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OUT OF THIN AIR...

A Guide to Aerial Theory, Design and Propagation

a practical WIRELESS publication

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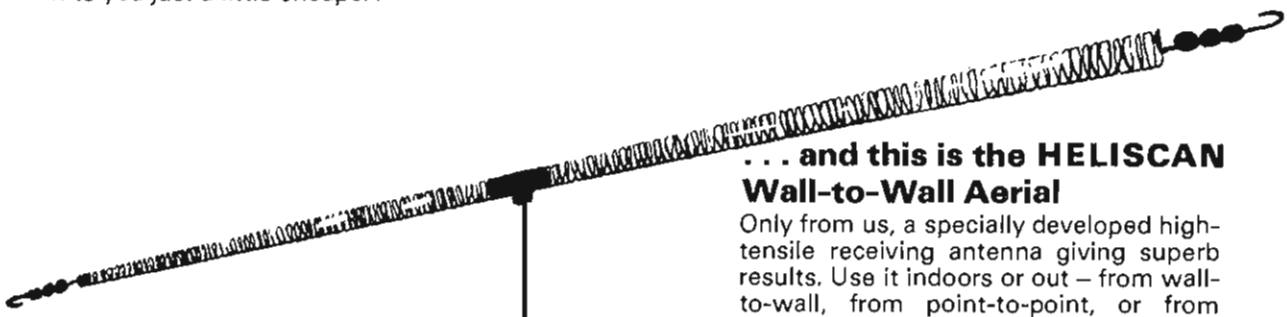

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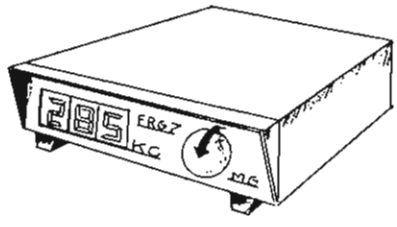

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OUT OF THIN AIR

A PRACTICAL WIRELESS PUBLICATION

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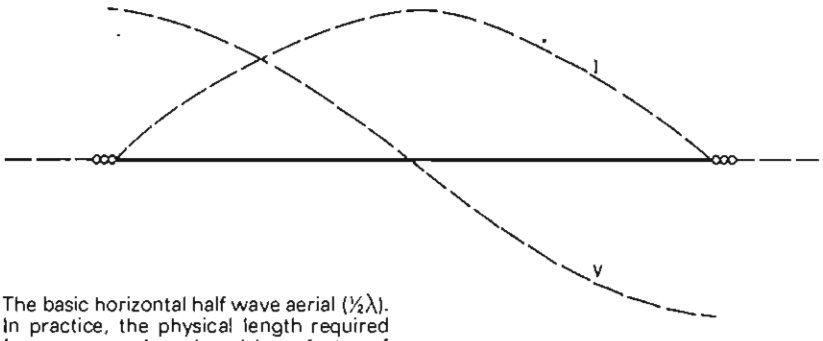
AERIAL DATA

Basics

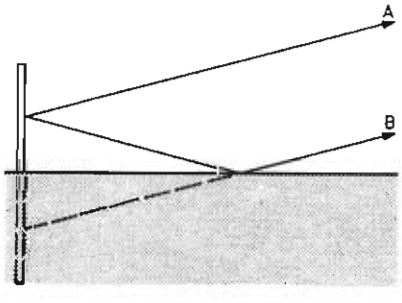


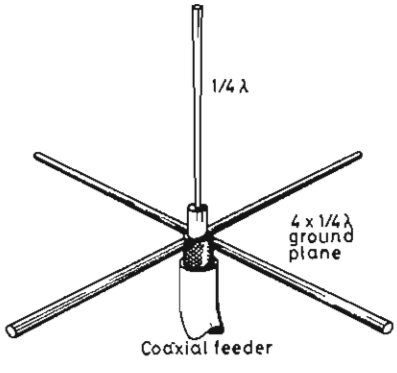
The basic horizontal half wave aerial (½λ). In practice, the physical length required for resonance is reduced by a factor of 0·95 (0·95 x ½λ) due to the effect of insulators and nearby objects. A simple formula for the practical half wave aerial is 143/F (MHz) metres. At resonance the induced voltage V will be maximum at the ends of the aerial (high impedance) while the current I will be maximum at the centre.

The basic Marconi aerial is a quarter-wave vertical with the lower end close to the ground, and it is used mainly on the lower frequencies. If this aerial is erected over a perfectly conducting ground then an image of the aerial is formed, which simulates a half-wave aerial. In practice the 'perfect' earth is formed from a number of long wires (radials) laid on or just under the surface of the earth.

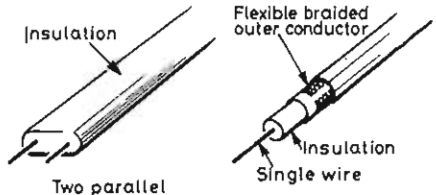
It is not necessary for the aerial wire to be physically the correct length for a particular frequency or wavelength. It can be made shorter or longer electrically to achieve the same state of resonance by using an aerial tuning unit (a.t.u.).

At higher frequencies, such an aerial is commonly mounted well above earth, and relies upon λ/4 radials entirely for its reflecting "earth plane." Such an aerial is known as a ground-plane.





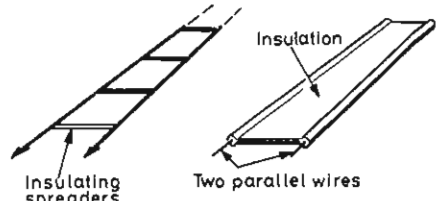
Feeders



(a) Nominal impedance 70–80 ohms

(b) Nominal impedance 50–80 ohms

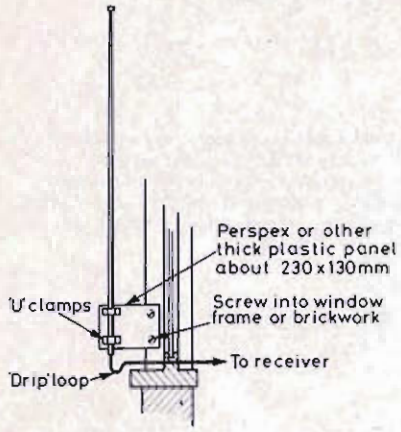
Since the aerial should be located in the clear and generally as high as possible to produce maximum signal strength it is necessary to use a feeder to connect the aerial to the receiver. Low impedance feeders may be flat twin (a), coaxial (b) or flat ribbon (d). High impedance feeders consist of two wires spaced apart by insulators every foot or so (c).



(c) Typical impedance 600 ohms

(d) Nominal impedance 240–300 ohms

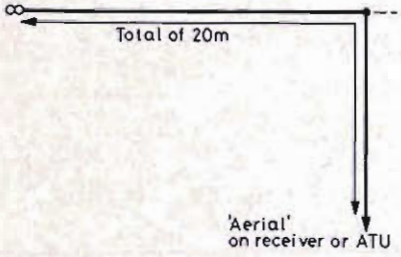
Rods and Whips


Perspex or other thick plastic panel about 230 x 130mm
'U' clamps
Screw into window frame or brickwork
To receiver
Drip loop

For the flat-dweller, often without access to a roof or loft space, the only answer may be a vertical rod aerial 3 or 4m long, made from aluminium or copper tubing. An a.t.u. is essential here to bring the aerial to resonance on the various bands. Being very short this aerial will perform better on the higher frequency bands such as 10 and 15m. A commercial whip aerial, with a base-mounting insulator, of the type intended for mobile use can also be useful in this situation.

Long Wire

A long length of copper wire, with one end connected to the receiver, is probably the most commonly used aerial. For best results it should be erected out of doors. The inverted "L" aerial is a good all-round performer especially if the vertical section can be 7m or more long. If the overall length is around 20m it will function well on the amateur bands without an aerial tuning unit but an a.t.u. will make it even better.



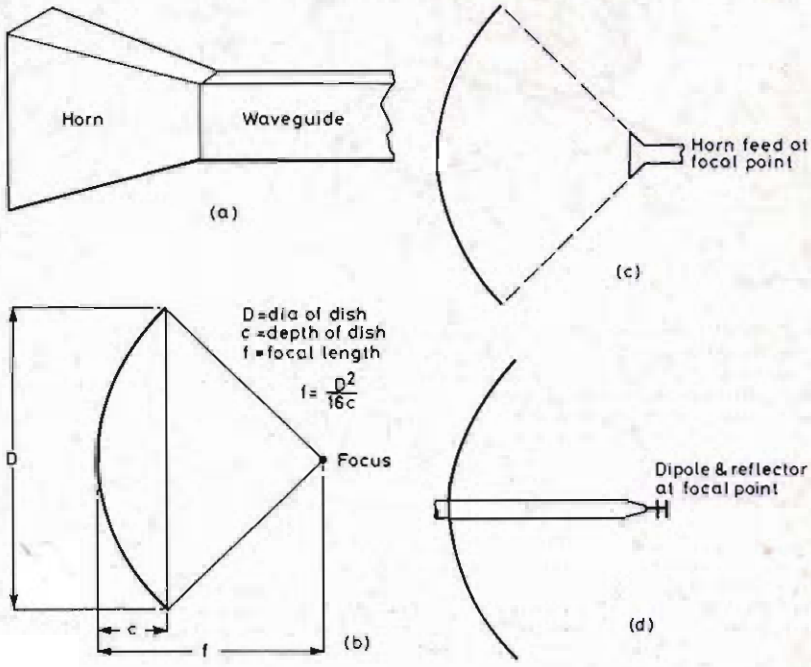
The combination of horizontal and vertical polarisation will help with DX signals where the received signal's polarisation can vary considerably from minute to minute.

Microwaves

Radio frequency signals of centimetric wavelength are carried to a receiver, or from a transmitter, by a rectangular-section tube called waveguide, whose internal dimensions will impose limits on the upper and lower cut-off frequencies, in much the same way that ordinary aerials exhibit a critical resonant frequency.

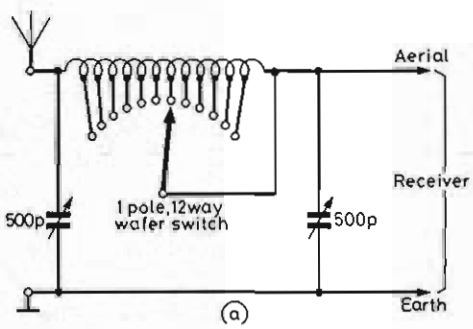
A simple microwave antenna, the pyramidal horn (a) is basically a flared-out extension of the waveguide, its surfaces envisaged as having an infinite number of radiating elements. An analogy would be a megaphone.

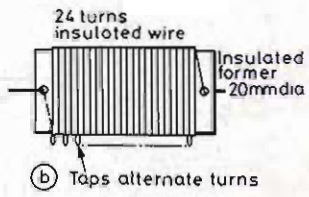
The parabolic reflector (dish) as shown (b) may be compared to a torch or headlight where the light source is at the focal point. The dish may be fed from the front (c) by a small horn at the focal point, or from the rear (d) by waveguide, using a reflector and dipole to suit the frequency. The gain and beamwidth of a dish is dependent upon its diameter in relation to the operating frequency. Using the formula for generating a parabola, dishes may be constructed in fibre-glass and the reflective surface covered with kitchen foil, alternatively, fine mesh wire netting, although this latter method would result in some losses.



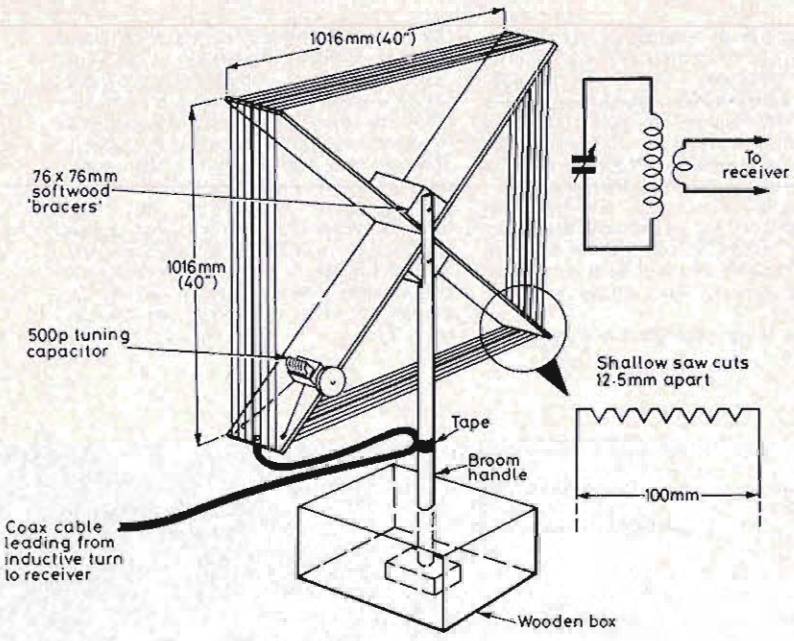
Aerial Tuning Unit

For best results an end-fed wire aerial or rod aerial should be matched to the receiver input circuit with an Aerial Tuning Unit (a). The inductor (b) is wound making a loop every other turn, the loops then being soldered to the switch tags. Fit each tuning capacitor with a calibrated knob or dial and number the switch positions. Adjust the capacitors and switch position for maximum signal strength noting that the three adjustments are very much inter-dependent. Log dial and switch readings for future reference.





MW Loop



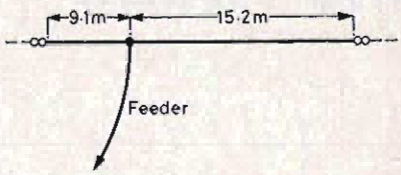
For frequencies between 500kHz and 2MHz the loop aerial takes a lot of beating. It consists of 7 turns of wire (5 or 6 turns for higher frequencies) around a wooden framework as illustrated. The ends of the wire connect to a 500pF tuning capacitor. A second wire, wound around the centre turn connects to a coax cable which goes to the aerial and earth sockets on the receiver or preferably to a balanced input.

The loop forms a tuned circuit in conjunction with the capacitor with the inductive loop providing a low impedance feed to the receiver. The capacitor has to be tuned for each frequency and the selectivity is excellent. The loop is highly directional and by rotating it, interfering stations can be virtually eliminated. The tuning is very sharp and it is advantageous to fit either a slow motion drive to the capacitor or to wire a small value variable trimmer in parallel with it (10pF to 20pF).

The gain is not as high as that of a long wire aerial but this is more than outweighed by the much improved signal-to-noise ratio and the directional characteristics. The direction of a station can be determined within a few degrees by nulling it out to take its bearing. The broom-handle can be fitted into a box as shown with the bottom fitting into a recessed slot to prevent it slipping.

The main frame can be made of 6mm thick plywood or softwood. The wires should be wound very tight and should be kept that way (under tension the wire tends to stretch slightly). The softwood blocks merely act as bracers and as supports for the broom handle.

Windom



A useful general coverage aerial for the h.f. bands is the Windom which uses a single wire feeder tapped on to the horizontal wire. An aerial length of about 24m will work especially well on the 13,25 and 49 metre bands.

Planning Consent

In the UK, any aerial support erected at a height exceeding 10 feet above ground level is subject to the Town and Country Planning Acts. Before embarking on any major aerial installation, it is advisable to contact the local Council Surveyor, and if necessary to apply for planning permission.

Frequency Bands

SHORT WAVE BROADCAST BANDS

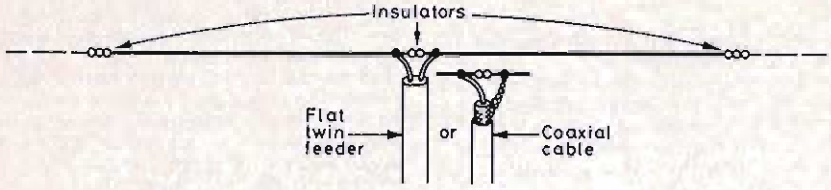
Band (metres)	Frequency (MHz)		Dipole Length (m)
120	2·300 to	2·495	—
90	3·200	3·400	—
75	3·900	4·000	—
60	4·750	5·060	—
49	5·950	6·200	23·17
41	7·100	7·300	19·81
31	9·500	9·775	14·63
25	11·700	11·975	11·89
19	15·100	15·450	9·14
16	17·700	17·900	7·92
13	21·450	21·750	6·58
11	25·600	26·100	5·54

SHORT WAVE AMATEUR BANDS

Band (metres)	Frequency (MHz)		Dipole Length (m)
160	1·800 to	2·000	78
80	3·500	4·000*	39
40	7·000	7·300**	20·12
20	14·000	14·350	10·06
15	21·000	21·450	6·7
10	28·000	29·700	4·88

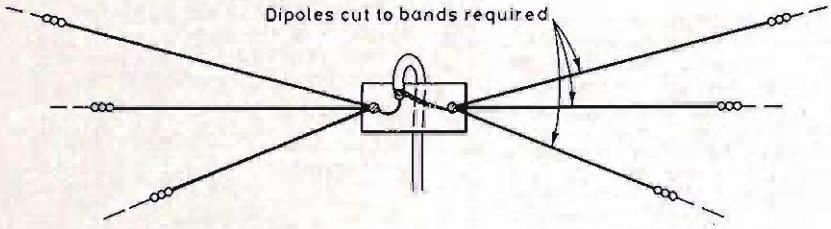
*UK 3·500-3·800
**UK 7·000-7·100

Half Wave Dipole

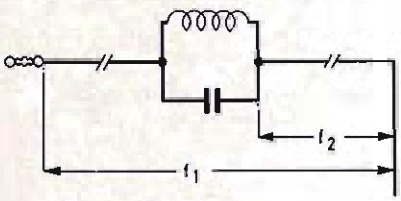


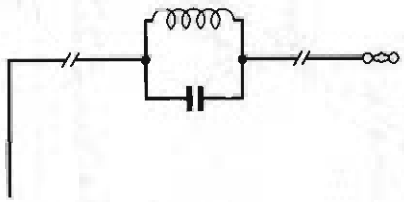
As the impedance at the centre of a half-wave aerial is approximately 70 ohms, flat twin or coaxial feeders will provide a good impedance match to the aerial ensuring maximum signal transference. The aerial, length calculated from the formula given, is cut at the centre and an insulator inserted, the wires of the feeder being connected either side of the insulator.

Multiband Dipole



If dipoles are required for optimum performance on several frequency bands they can be connected in parallel at their centres and fed with a common feeder thus providing multiband facilities in a minimum of space. The ends of the dipoles may be tied off to any convenient supports and the dipoles need not all be in the same plane. Note that a dipole cut for, say, the 7MHz amateur band, will be three half waves on the 21MHz amateur band thus eliminating the need for a separate aerial for that band. Another approach, known as the Trap Dipole, uses parallel tuned circuits (traps) in the dipole elements. The length f_1, for example, might be appropriate for 14MHz, and the length f_2 for 21MHz. The tuned circuits would be designed to resonate at 21MHz, effectively isolating the end sections of the dipole from the feeder at that frequency. On 14MHz, the tuned circuits would have a low impedance, and the whole of the elements come into use. Some trimming of the sections compared to the calculated lengths, is necessary to compensate for the effect of the traps.

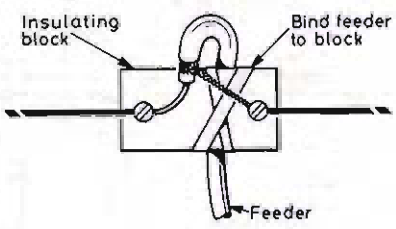




Construction

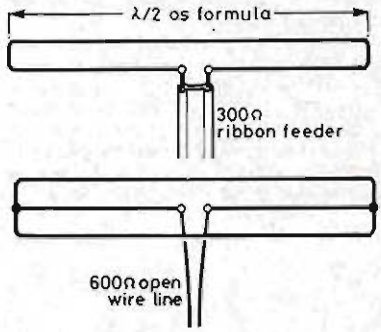
A practical method of feeding the aerial with low impedance feeder. The loop in the top of the feeder is essential to prevent the ingress of rain and dirt. The end of coaxial cable can be sealed with plastic insulating tape or compound.

"T" connectors providing mechanical anchorage and watertight termination for the feeder cable are also available from a number of our advertisers catering for the radio amateur.



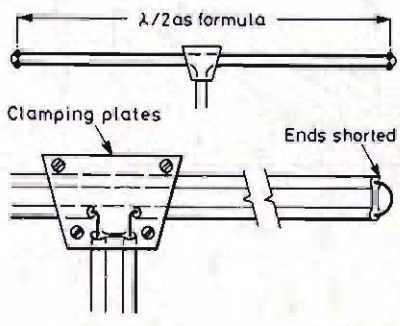
Folded Dipole

The folded dipole (a) will transform the input impedance by a factor of 2^2 or $4 \times 70 = 280$ ohms so that it can be fed with a flat ribbon feeder of 300 ohms impedance, provided the wires forming the folded dipole are the same diameter. If a three-fold dipole is used, the input impedance will be $70 \times 3^2 = 630$ ohms which will provide a good match to an open line feeder.



Construction

A practical folded dipole using 300 ohm ribbon feeder for both the aerial and the feeder. One conductor only of the aerial is cut at the centre and the feeder inserted and the joints soldered. The junction should be clamped between pieces of insulating material and properly waterproofed.



MULTI-ELEMENT AERIALS

Multi-element aerials fall into two basic groups: those with more than one element directly driven, and those with one element driven and the remainder parasitically excited—in other words picking up radiation from the driven element and re-radiating it. In both cases, the radiation from the various elements interacts to give increased field strength in some directions and reduced strength in other.

This description assumes the aerial is being used for transmission, but since aerials behave in a reciprocal fashion, it is equally true for reception, the "driven" elements being those that are connected via a feeder to the receiver.

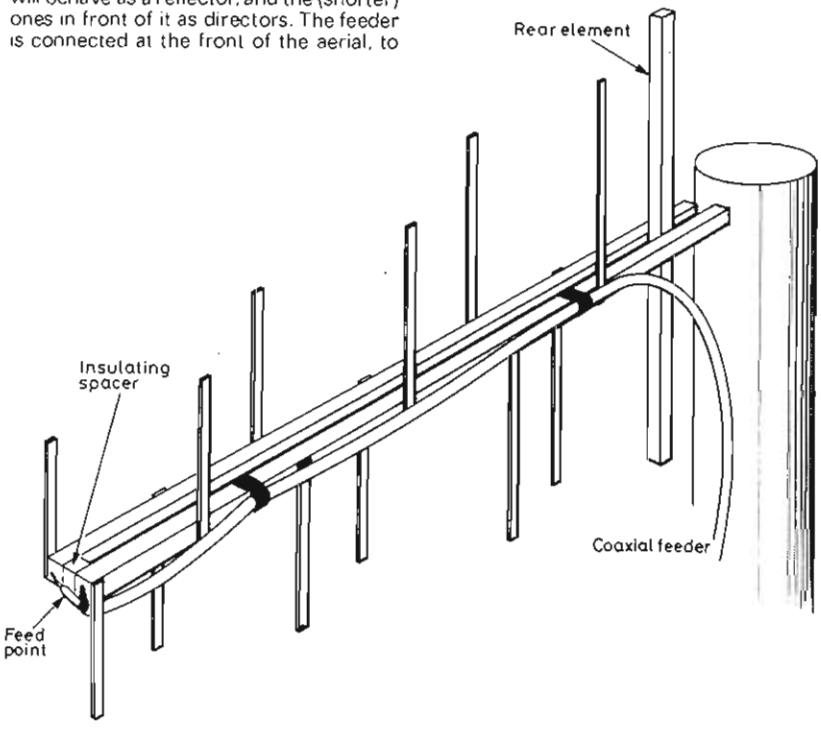
Log-Periodic

One of the disadvantages of the Yagi is its fairly narrow bandwidth. Where a broad range of frequencies is to be covered, and there is no space for multiple aerial arrays, the Log-Periodic aerial may be useful, though its gain is lower than a Yagi.

The name arises from the fact that there is a constant mathematical relationship in the length and positioning of each element, compared with its predecessor in the series. All elements, except the rearmost reflector, are driven, though not all are active at one time.

A simplified explanation of the operation is as follows. For any signal within the bandwidth of the aerial, only one element will be near resonance. That element will act as a dipole, the (longer) one behind it will behave as a reflector, and the (shorter) ones in front of it as directors. The feeder is connected at the front of the aerial, to the transmission line formed by the twin parallel booms on which the elements are mounted. Alternate half-elements are connected to opposite booms, to provide the necessary phase-change between successive elements.

The length and spacing of successive elements reduces from the back by a factor n, less than 1. For a given bandwidth, a shorter array has fewer elements and a lower gain, and a lower value of n.



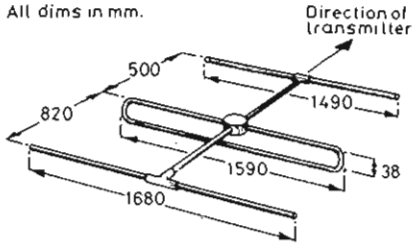
Yagi

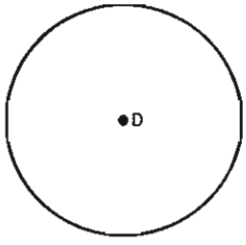
The most common version of the parasitic aerial array, the Yagi, will be familiar to all in its application to v.h.f. and u.h.f. TV and to v.h.f. f.m. sound reception. Its basic form, the "H," is formed by adding a single rod to a half-wave dipole, spaced some small fraction of a wavelength from it. By making the rod slightly longer than the dipole, it acts as a reflector, modifying the response pattern to a cardioid (heart-shape) pattern. In practice this is not a perfect cardioid, and there will an unwanted rear lobe.

Adding a second rod, slightly shorter than the dipole, on the opposite side to the reflector, will reinforce and narrow the main lobe of the response pattern. A 3-element Yagi suitable for v.h.f. f.m. sound reception is shown. The frequency of maximum response is 95MHz.

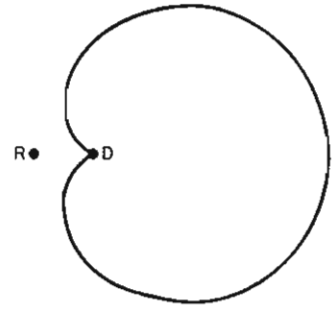
Further directors may be added in front of the first, each slightly improving the gain of the aerial array, up to a limit of about 36 elements, after which no significant increase is obtained.

Adding parasitic elements reduces the impedance of the dipole, as seen by the feeder, and a folded dipole is frequently used, to help to compensate for this.





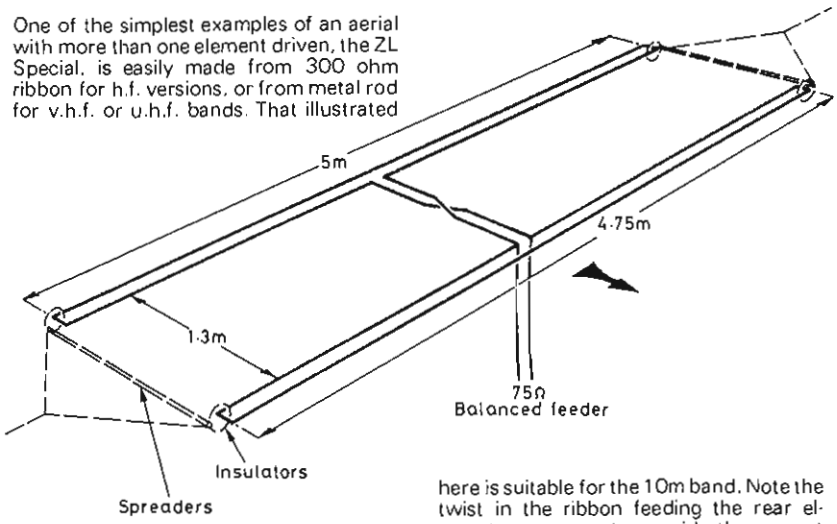
Circular radiation pattern of dipole (viewed end-on)



adding a reflector

ZL Special

One of the simplest examples of an aerial with more than one element driven, the ZL Special, is easily made from 300 ohm ribbon for h.f. versions, or from metal rod for v.h.f. or u.h.f. bands. That illustrated



here is suitable for the 10m band. Note the twist in the ribbon feeding the rear element, necessary to provide the correct phasing.

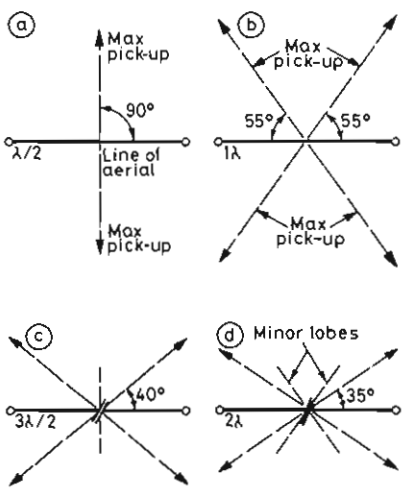
Note

We were guilty of the sin of over-simplification in the section on Yagi aerials. Adding a parasitic reflector to a dipole cannot produce a true cardioid response pattern, because of the losses inherent in energising the reflector from the field radiated from the dipole.

The response pattern is of the same general form as a cardioid, varying in shape according to element spacing. A true cardioid is produced by having two driven elements, appropriately phased, as in the ZL Special.

Directivity

Signal pick-up of a half-wave aerial is maximum at right angles to the line of the wire (a). If the wire is one wavelength long maximum pick-up is from four directions (b). By choosing the right length of aerial and adjusting its orientation the maximum pick-up lobes can be made to cover all the land areas of the world.

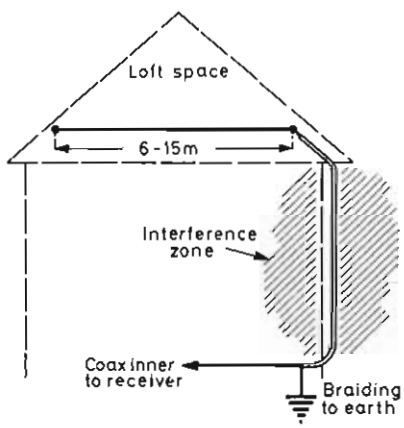


Longer aerials result in the appearance of minor lobes (c) and (d) which reduce directivity and improve all round coverage With an aerial many wavelengths long maximum reception is along the line of the wire.

Indoor Aerials

A long wire aerial can be erected in restricted loft spaces and inside roofs even if it means draping it round the rafters! If electrical noise is a problem then the lower part of the aerial can be a length of coaxial cable with the outer screen connected to the receiver chassis or earth.

A similar aerial can be strung around a room, and even quite a small room will enable a 12 metre length to be used.



One convenient form of aerial can be obtained by using the coaxial cable of a TV aerial, the outer braiding being connected to the aerial socket of the receiver. Important!—disconnect the TV aerial from the TV set before using it in this form.

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AERIALS for 160 Metres

J.R.GREEN G3WVR

A number of readers considering building the VMOS Top Band Transmitter, which appeared in the July issue of *PW*, have requested further details of suitable aerial systems for use on the 160 metre band.

The problem on this band is, of course, the very long length of wire required to produce a true quarter-wavelength aerial system, something in the region of 39 metres, or 128 feet. Shorter aerial systems can be tuned to resonance by means of a loading coil, but there will inevitably be some loss of power in the inductor used, and the shorter the aerial, the greater the loss.

Long-Wire Aerials

Some may have gardens long enough for 128 feet of wire, strung to a convenient tree, or a pole at the end of the garden. However, height is important, and for field days and the like, a kite or (slightly more predictable in behaviour) a balloon may usefully be pressed into service as a practical alternative to a skyhook!

A suggested system is shown in Fig. 1. This may be connected directly to the output socket of the transmitter, or via the shortest practicable length of 50Ω coaxial cable.

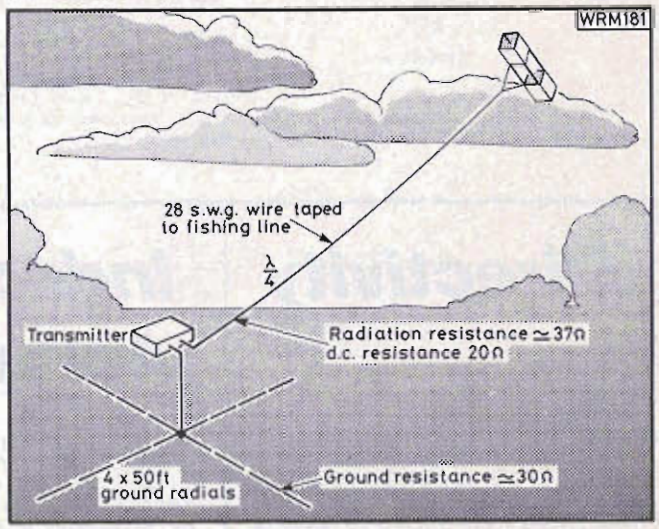


Fig. 1: A kite or balloon-supported, quarter-wave aerial system

A Tree Aerial

By using an eighth-wavelength aerial, with a loading coil, use can be made of a 60ft tree, as shown in Fig. 2. The aerial should be connected to the tap on the coil which gives the maximum reading on the ammeter.

Using a catapult to erect an aerial can be a hazardous business, and the following procedure should be followed to minimise the risks. (See Fig. 3)

1. Spool out the wire as shown.
2. Make sure that the wire from the weight exits at the **top** of the catapult pouch.
3. Hold the catapult well away from yourself, and sideways.
4. Turn your head away before firing.
5. Always wear a glove—a thick one!
6. Make sure that there are no people, animals, or property around that could be injured or damaged by a foul shot.

Remember—catapults are dangerous.

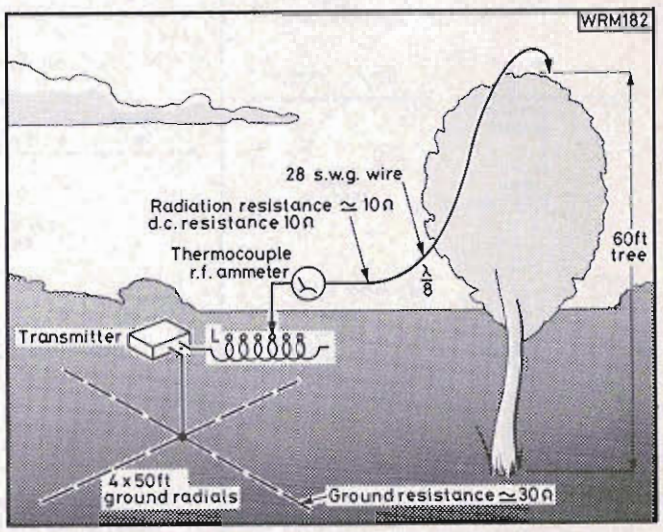


Fig. 2: An eighth-wave aerial system, erected with a catapult and lead weight. Loading coil L is 40 turns of 22 s.w.g. on a 50mm dia. former, tapped every 4 turns

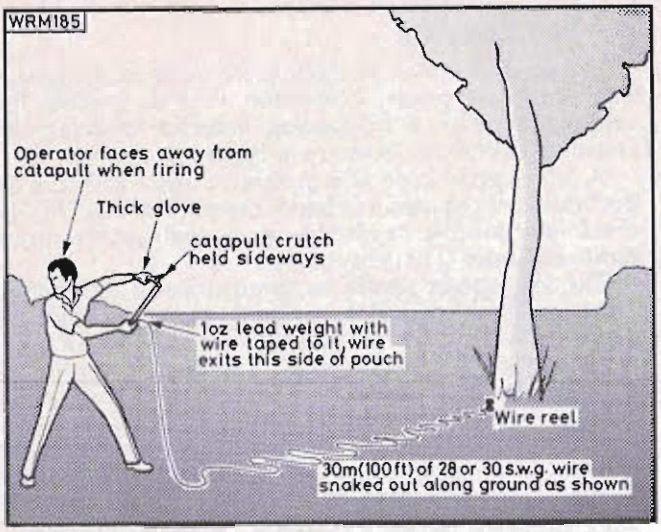

WRM185
Operator faces away from catapult when firing
Thick glove
catapult crutch held sideways
1oz lead weight with wire taped to it, wire exits this side of pouch
Wire reel
30m(100ft) of 28 or 30 s.w.g. wire snaked out along ground as shown

Fig. 3: Erecting an aerial by catapult. The operator should stand about 30m from the trunk of the tree

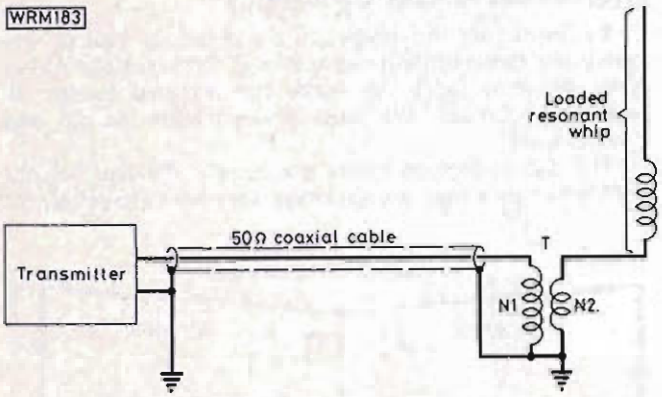


Fig. 4: Loaded whip aerial for mobile use. Transformer T is an r.f. matching transformer with step-down ratio N_1:N_2 of around 2:1–3:1 (see Fig. 5)

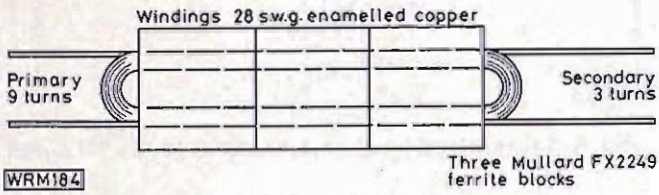


Fig. 5: An r.f. matching transformer suitable for use in the loaded whip aerial system of Fig. 4

Mobile Whip Aerial

For mobile use, the aerial will be very much less than a quarter wavelength long. A whip aerial, such as shown in Fig. 4, must be accurately tuned to resonance by means of the loading coil at its base, or centre. In other words, its impedance must be real.

The real impedance plus losses should be less than 50Ω, and a step-down matching transformer will be required, with a turns ratio N_1:N_2 of 2:1 or 3:1. This transformer can be similar to that used for T1 in the VMOS Transmitter, taking the form shown in Fig. 5.

Vertical aerials for low-frequency ground-wave propagation have been a topic of keen interest to the author for many years. In particular, due to their sheer impractical size, the question of optimum loading is paramount in their design.

Theory

To avoid making the theoretical argument unnecessarily complicated, the basis of this section rests on two simple formulae which provide a good approximation to more complex methods:

$$\text{Aerial Efficiency} = \frac{R_{RAD}}{R_{RAD} + R_{DC} + R_G} \quad \ldots\ldots\ldots (1)$$

where R_{RAD} = The radiation resistance of the aerial (dependent on useful length and height);
R_{DC} = The ohmic d.c. resistance in all wire, coils, and radials;
R_G = Ground losses, i.e., Earth resistance.

$$\text{Near Field Strength } E \text{ (mV/metre)} = \frac{377 \times I_a \times h_e}{\lambda \times D} \quad \ldots\ldots\ldots (2)$$

where I_a = Aerial current at the base of the aerial (amps);
h_e = Effective height of the aerial;
λ = Wavelength;
D = Distance from aerial (kilometres).

Equation (2) is taken from the ITT *Reference Data for Radio Engineers*. Note that h_e and λ must be in the same units.

Effective Height

The Effective Height (h_e) of a grounded vertical aerial is equal to the height of a vertical wire producing the same vertically polarised field as the actual aerial, provided that the vertical wire carries a current that is constant along its entire length and of the same value as the current at the base of the actual aerial. For the more mathematically minded, $I_a \times h_e$ is the value of the integrated sinusoidal current in the actual aerial of physical height h.

The diagram Fig. 6 shows clearly how this definition makes sense, the areas "A" and "B" being equal for the correct value of h_e. Typically, h_e would range from $0{\cdot}5h$ for a very short vertical aerial, such as a base-loaded whip, to $0{\cdot}66h$ for a quarter-wave vertical.

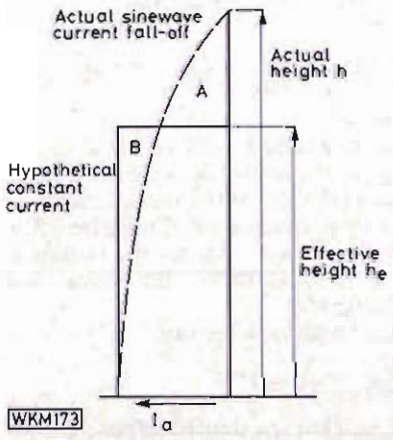


Fig. 6: Relationship of Actual Height and Effective Height of a λ/4 vertical aerial. Areas "A" and "B" are equal

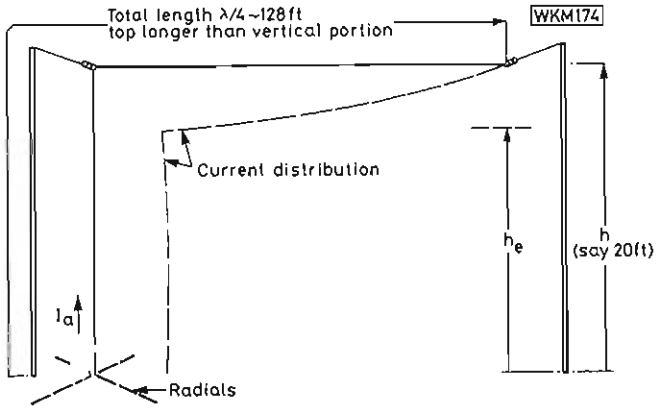


Fig. 7: Current distribution and Actual and Effective Height relationship for an Inverted "L" aerial

Practical Implications

On the basis of theory, we may assume that:

1. From Equation (1), we require a large R_{RAD} (which means a large aerial, and a small R_{DC} (which means thick, heavy wire) and a small R_G (which means a field full of radials).
2. From Equation (2), both I_a and h_e should be as large as possible.

These implications are not really very "practical" at all, but we can at least examine them to make the best use of what facilities are available. Let us first consider a commonly used amateur aerial, the Inverted "L". The diagram Fig. 7 shows a typical inverted "L" whose top section is much longer than the vertical section, and hence the current distribution is almost constant along the vertical portion. This gives an effective height h_e which is nearly equal to the actual height, i.e., about 18ft, which is very poor compared with, say, a λ/4 vertical, whose effective height would be 128 × 0·66 = 84ft, but better than a 20ft short vertical, whose h_e would be only 10ft.

As regards radiation resistance, the inverted "L" is fairly good (i.e., high) because of its λ/4 length, but poor in respect that most of its radiation is horizontally polarised and very high-angle due to its low height.

The vertically-polarised radiation could be increased by top loading in a non-radiating way. This will reduce the radiation resistance, thereby increasing I_a in the vertical portion, and a greater vertically-polarised field strength will result, although the actual aerial efficiency is lower.

For the standard inverted "L", we might have

$$R_{RAD} = 30\Omega, \quad R_{DC} = 5\Omega, \quad R_G = 20\Omega$$

giving:

$$\text{Efficiency} = \frac{30\Omega}{30\Omega + 5\Omega + 20\Omega} = 55\%$$

and an effective height of 18ft.

The first step towards increasing I_a without worsening h_e is to use "T" top loading, as shown in Fig. 8. Note that the current distribution splits at the top of the vertical radiator and, to a first approximation, cancels out. This eliminates horizontally-polarised radiation and reduces the radiation resistance, increasing I_a and actually increasing the vertically-polarised field strength.

Note that the efficiency might now be, say:

$$\frac{20\Omega}{20\Omega + 20\Omega + 5\Omega} = 45\%$$

but the higher value of I_a still has the desired effect.

LC Top Loading

The aerial may now be made more compact by using a smaller top composed of multiple wires to increase the capacitance, plus a top-loading inductor to bring the system to resonance, as shown in Fig. 9.

A large capacitance C is preferable, since then less inductance L is required and hence there is less loss (R_{DC}) in the L, and a wider bandwidth in the resonant frequency due to the lower Q of the system.

The top section should be symmetrical if possible, in order to cancel horizontally-polarised radiation. Since the actual vertical portion will be small compared with a quarter wavelength, the LC resonant frequency on its own will be only slightly higher than the overall aerial resonance, which is reduced by the extra radiator inductance.

Hence, it has been shown that top loading, although nominally not improving overall antenna efficiency, can usefully channel "wasted" horizontally-polarised radiation into improved vertically-polarised radiation, although I daresay that many users of inverted "L" aerials do not consider the horizontal component to be wasted!

Improving Aerial Efficiency

By improving the efficiency we could, of course, improve the radiated field strength still further, since all we have done so far is to make the radiated energy all vertically-polarised. We must now consider the d.c. and ground losses.

The d.c. resistance losses are usually the least of our problems, since they are generally very low. However, the

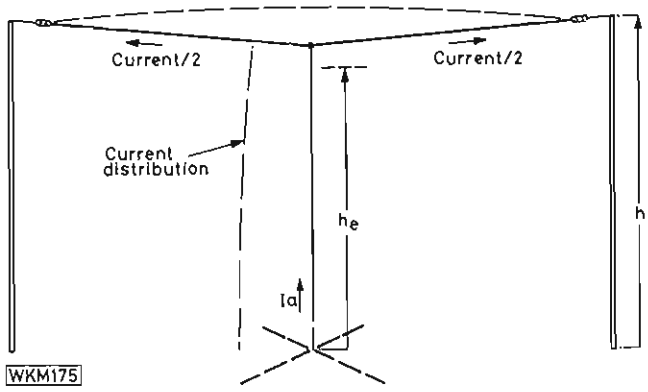


Fig. 8: Current and height relationship for a "T" aerial

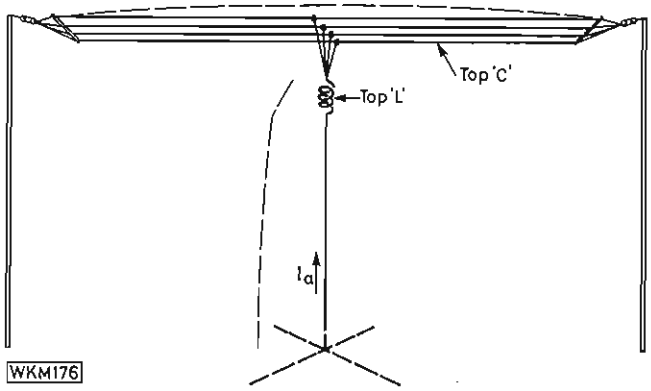


Fig. 9: A "T" aerial with multiple top span giving added capacitance loading, and top loading inductance

Comparison of an "Ideal" and a Practical Aerial

Ideal λ/4 Vertical	**Practical Vertical**
Actual height (h) 128ft Effective height (h_e) 84ft	Actual height (h) 38-40ft Effective height (h_e) 35ft
$R_{RAD} = 37\Omega$ $R_{DC} = 0\Omega$ $R_G = 0\Omega$	$R_{RAD} = 10\Omega$ $R_{DC} = 2\Omega$ $R_G = 10\Omega$ } approx.
Efficiency = 100%	Efficiency = say 45%

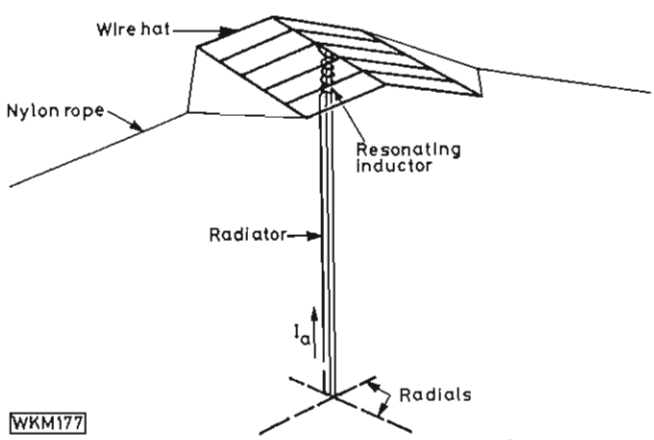
Aerial current for 7W r.f. input to aerial system
(i.e., 10W d.c. input to transmitter p.a.)

$W = I^2 R_{total}$ $I_a = \sqrt{\frac{W}{R_{total}}}$ $= \sqrt{\frac{7}{37}}$ $= 0{\cdot}435A$	$W = I^2 R_{total}$ $I_a = \sqrt{\frac{W}{R_{total}}}$ $= \sqrt{\frac{7}{22}}$ $= 0{\cdot}565A$

Note that I_a is higher for the top-loaded vertical since R_{total} is lower. This helps to compensate for its reduced efficiency

Field strength at a distance *D* of 1km

$E = \frac{377 \times I_a \times h_e}{\lambda D}$ $I_a = 0{\cdot}435A$ $h_e = \frac{2}{3} \times \frac{\lambda}{4}$ $E = \frac{377 \times 0{\cdot}435 \times 0{\cdot}67 \times \lambda}{\lambda \times 1 \times 4}$ $= \frac{377 \times 0{\cdot}435 \times 0{\cdot}67}{4}$ $= 27$mV/metre at 1km	$E = \frac{377 \times I_a \times h_e}{\lambda D}$ $I_a = 0{\cdot}565A$ $h_e = \frac{35}{128} \times \frac{\lambda}{4}$ $E = \frac{377 \times 0{\cdot}565 \times 35 \times \lambda}{\lambda \times 1 \times 128 \times 4}$ $= \frac{377 \times 0{\cdot}565 \times 35}{512}$ $= 14{\cdot}6$mV/metre at 1km
This is the "ideal" best possible figure	This is a "practical" realisable figure



use of a large capacity hat of reasonably thick wires plus an inductor wound from the thickest available wire (consistent with weight constraints) is advised, with the actual radiator constructed from coaxial cable braid, or aluminium tubing salvaged from Band I TV aerials or Band II f.m. aerial booms.

In view of the weight involved, the system may be adapted to a single guyed mast as shown in Fig. 10. The ground losses, however, usually present the major headache in terms of aerial efficiency, because not many amateurs

Fig. 10: Top-hat loading for a single guyed mast aerial. For maximum efficiency, the guy ropes should be led down at the shallowest possible angle, so that the top hat encloses the minimum amount of the vertical radiating element

have a convenient field in which to bury the recommended 200 or so $\lambda/2$ radials which a medium wave broadcast station, for example, would use with its aerial.

A very ancient radio data book studied by the author some years ago suggested that 4 radials, instead of 200, would reduce the field strength to around half of the theoretical maximum, and a commonsense deduction suggested also that the radials need be no longer than the actual physical height of the radiator.

Experiment has shown that four 50ft radials offer quite a good ground, certainly much better than an earth stake, and if these cannot radiate in all directions from the aerial

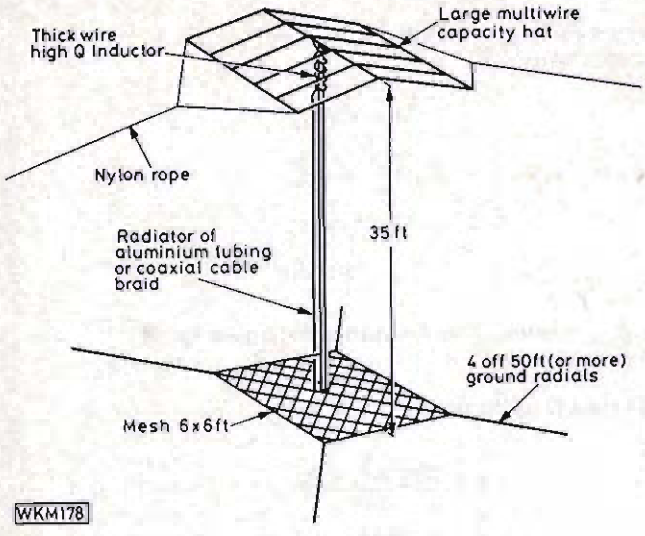


Fig. 11: More practical details of the author's top-loaded vertical aerial and the associated ground-plane

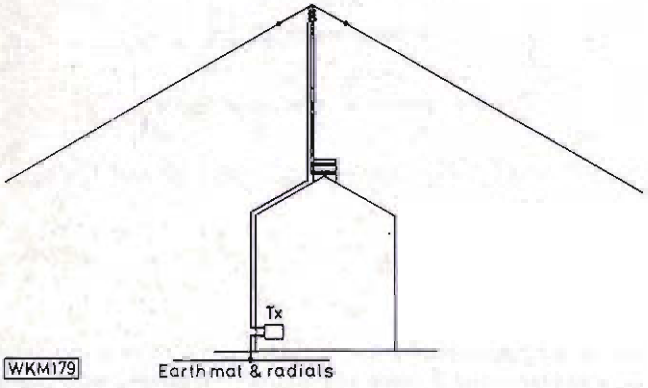


Fig. 12: If space does not permit a mast in the garden, the aerial of Fig. 11 may be mounted on the house-top

base, then commonsense suggests that they should run under the aerial's top section, although this may well affect the directivity. In the immediate vicinity of the aerial base, the ground current is highly concentrated and an earth mat of many interconnected wires, or chicken-wire mesh should be used.

To summarise the various recommendations, the author's "practical" 160m top-loaded vertical is shown in Fig. 11. If garden space does not allow the erection of a mast, the aerial may be mounted atop the house, on a chimney stack for instance, as shown in Fig.12. ●

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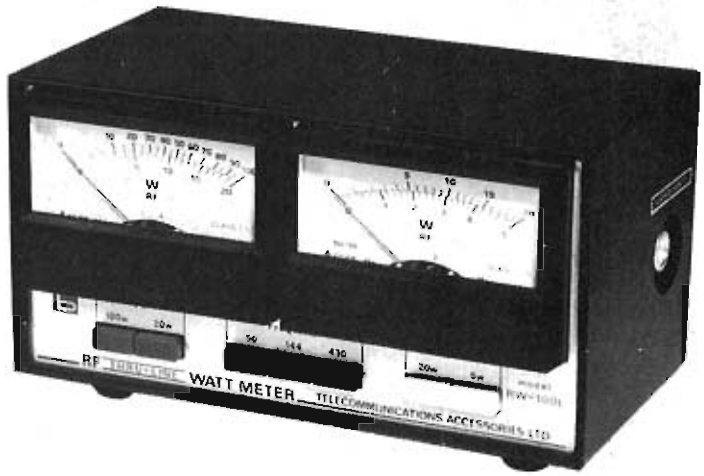

The problems of coupling transmitters to aerials are well known and are discussed in detail by F. C. Judd elsewhere in this issue. Briefly, the object is to achieve an optimum transfer of the r.f. energy from the transmitter power output stage(s), along the feeder to the radiating device, which calls for quite precise matching.

One of the most convenient methods of measuring the parameters involved is to use a *bridge,* which is placed in-line with the aerial and gives a visual indication of the forward and reflected power levels present.

A variety of types are available costing from a few pounds to several hundreds. If meaningful *measurements* are to be made, however, the very cheap instruments are unlikely to afford the accuracy required. Indeed they can, in certain circumstances, introduce problems if their own input and output characteristics do not match those of the circuit under test.

Assuming the average amateur's budget does not extend to a Bird Thruline with several plug-in elements, one is faced with the decision of what to buy for a reasonable outlay which measures, rather than indicates.

Telecommunications Accessories Ltd. (until recently known as Antenna Specialists UK Ltd.) import a v.s.w.r. bridge and power meter combination, type **RW100L** which is intended for the commercial mobile market but is equally suited to amateur applications.

Two meters, each with a 76mm (3in) display area, are employed, so that forward and reflected power can be directly compared without the arduous business of having to switch between the two functions and memorise the values from one to the other. Full-scale deflection is selected by two push-buttons in each mode, the readouts being 0–20, 0–100 watts forward and 0–5, 0–20 watts reflected.

Input and output is by "N" type connectors into 50Ω ports. A very close match to the 50Ω circuit under test is maintained by the bridge.

Three switched frequency ranges are provided covering 50–430MHz in the one unit, without the use of separate directional couplers. The meter under test proved very easy to operate and read, its accuracy being quite remarkable when compared to a much costlier professional model.

Although the instrument is intended for laboratory or "shack" use, its rugged construction also makes it suitable for applications in the field where a less expensive, high integrity meter is called for.

There are other less-sophisticated devices within the range available, and the distributors have indicated their willingness to supply detailed information on the product line when requested to do so.

★ specification

Frequency range:	50–430MHz in 3 ranges
Power ranges:	0–20 and 0–100W forward 0–5 and 0–20W reflected
Input and output impedance:	50Ω
Connectors:	50Ω "N" type
Size:	190 x 108 x 114mm (7½ x 4½ x 4½ins)
Weight:	1·75kg (3·8lbs)
Price:	around £130

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THE SUN'S INFLUENCE

Ron HAM

Although our sun has little importance among the millions of stars in the Milky Way galaxy, it is very important to us here on earth, because it provides our light, heat and natural energy. The majority of stars, and our sun is no exception, are nuclear furnaces radiating waves, in varying degrees, across the electromagnetic spectrum. With the advent of the optical telescope in the 15th century, astronomers learnt much more about the stars, our sun and the planets which make up our own solar system.

Radio Astronomy

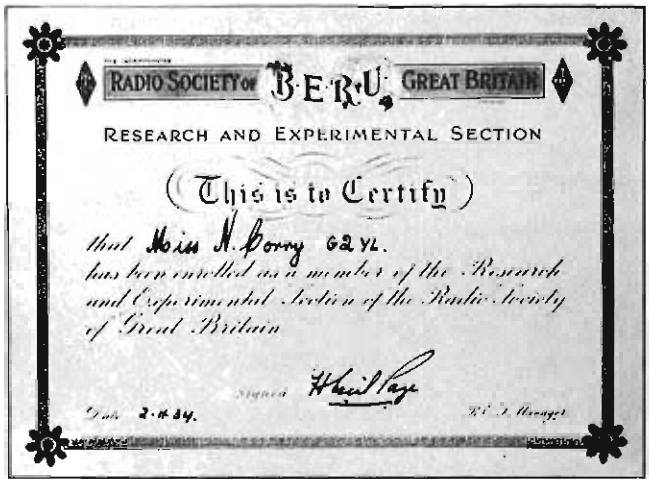
During 1931, American radio engineer Karl Jansky, using specialised apparatus, detected radio noise around 21MHz, coming from the Sagittarius arm of the Milky Way. At first, few people realised the significance of Jansky's discovery. After all, astronomical observations for at least the previous 300 years had been made with an optical telescope. To suggest that invisible waves coming from the stars could be recorded on a paper chart took a fair bit of understanding.

The fact that stars had been emitting radio waves for untold millions of years remained unknown until the art of making radio receivers was about 35 years old. It is generally accepted that radio waves travel at the speed of light, 186 000 miles per second, in other words almost 6 million, million miles in one year, or in astronomical terms, a light-year. For example, radio waves from the Crab nebula, in the constellation of Taurus, take some 3300 years to reach us, whereas radio waves from our sun, a mere 93 million miles away, are received on earth just 8·3 minutes after they are generated.

Radio Telescope

The work of a visual astronomer is limited to the hours of darkness and then the skies must be clear and, unless he is studying the moon, free of moonlight. A radio telescope, however, can record celestial radio waves at any time, unaffected by overcast skies, but its results are sometimes troubled with static from electrical storms and a variety of man-made interferences. Briefly, a simple radio telescope comprises a high-gain directional aerial, securely mounted and pointed toward the source being observed. In some cases an aerial head amplifier is used before the incoming signal is fed to the main receiver, usually a purpose-built superheterodyne, with a d.c. amplifier connected to its detector circuit to drive a pen recorder.

Although certain frequencies are set aside internationally for astronomical observations, a radio astronomer can use any part of the radio frequency spectrum providing that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RESEARCH AND EXPERIMENTAL SECTION

This is to Certify

that Miss N. Berry G2YL

has been enrolled as a member of the Research and Experimental Section of the Radio Society of Great Britain

Signed H. Lloyd Hayes

Date 2-11-54.

Fig. 1: The special Research and Experimental Section certificate issued to section members by the RSGB

Fig. 2: The 1935 shack of Miss Nell Corry G2YL. All her equipment, including the transmitter on the left, was home-brewed. With this station, she established a world record on 27 October, 1935, by working all continents on 10m in 6 hours and 20 minutes. The log books, QSL cards and Morse key used on this historic occasion are now in the author's collection

it suits his observational requirements and is free of terrestrial transmissions. For an amateur to make a useful contribution in the field of radio astronomy, he would need a very large aerial system with precise settings both in altitude and azimuth, a low-noise, high-gain receiver, and access to a computer, to extract any meaningful information from the data gathered during his observations. The high installation and running costs of a radio observatory prevent the majority of amateurs setting up such a project.

Radio Noise

The noise collected by a radio telescope is very similar to that which is generated within the wiring and components which make up the telescope's receiver. Therefore, it is important that this internal noise level is measured before the aerial is connected, so that the incoming waves are positively identified. When thermionic valves were used, a great deal of noise came from the valve itself and the high electrical currents flowing through its associated components. Much of this problem was overcome when transistors replaced valves, because they are far less noisy and require only a fraction of the current to drive them.

Short-wave Communications

From its birth toward the end of the 19th century, the story of radio has been a fascinating one. Very soon enthusiasts were building receivers, and transmitters, which allowed them to listen to signals travelling around the world, and enabled people from the ends of the earth to converse with each other. We owe a great deal today to those early radio amateurs who pioneered the signal paths around the earth, often when contemporary thinking said it was impossible.

Between the two world wars, great strides were made in opening up the short-wave bands for both communications and broadcasting. This work was exciting because there was much to learn about echoing and rough signals, fading, sudden ionospheric disturbances and sometimes complete and extensive radio blackouts. Scientists were aware then that the complex rays from the sun caused changes in the ionosphere which, of course, explained why short-wave signal paths via the ionosphere varied between day and night.

The Research and Experimental Section

The Radio Society of Great Britain, founded in 1913, has always encouraged its members to send reports of their findings to the Society for publication, and in the 1930s they set up a Research and Experimental Section, Fig. 1, which had separate groups and its own columns in the RSGB's monthly journal, the *T & R Bulletin*.

In January 1936, Miss Nell Corry G2YL, became author of the "28 Mc/s Group" report, which she compiled each month from her own 10m work and from information she received from amateurs and short-wave listeners around the world.

Fortunately for posterity, Nell was a very methodical individual and kept daily records of the 28MHz information she received, until early 1940, in a set of four diaries which have survived the passage of time and are now in the author's collection. Analysis of these diaries revealed that over the 4-year period 1936-1939, aurora was reported on 53 days, echoing on signals on 26 days, fadeouts on 140 days and a "hissing" noise on 107 days.

Solar Radio Noise

It was this "hissing" noise that was the important revelation, and further investigation by the author showed that during 1935, Denis Heightman G6DH, a member of the Research and Experimental Section, heard this strange "hissing" sound above the background noise of his 10m receiver. Denis, an experienced wireless operator, consistently noted that the "hissing" occurred only during daylight hours, and usually preceded a radio disturbance. Very soon he rightly concluded that the "hissing" noise was

The T. & R. Bulletin.

The "Hiss" Phenomenon.

A strange phenomenon, first observed by the writer in late 1935, was the appearance, at irregular times, of a radiation which took the form of a smooth hissing sound, when listened to on a receiver. It was pointed out by G2YL that on the days when hiss was heard that there had frequently been fade-outs or poor conditions on the high frequencies. G2GD has also noted that when the hiss has been received magnetic storms are also reported. On one day the hiss may only last for a few seconds and not be heard again that day. On other occasions it will last as long as five minutes, then disappear and reappear again within a few minutes, repeating the process several times. It invariably starts at a weak strength and gradually builds up to a maximum, then gradually fades away again. The phenomenon apparently originates on the sun, since it has only been heard during daylight, and it has been suggested that it is caused by a stream of particles shot off from the sun during abnormal activity.

May, 1937

Fig. 3: The final paragraph of Denis Heightman's article in the May 1937 edition of the *T & R Bulletin*
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Fig. 4: Flares occurring around a sunspot group, photographed by Cmdr Henry Hatfield with his spectrohelioscope on 28 May, 1978

coming from the sun, and in 1936 he reported his findings to the Editor of *Wireless World* and Professor (later Sir) Edward Appleton. Later, he outlined his observations in a comprehensive article published in the RSGB's *T & R Bulletin*, Fig. 3.

From Nell Corry's diaries and her journal reports, the author found that some 24 other radio amateurs and short wave listeners had heard the "hissing" noise and furthermore it was not limited to 28MHz, because, at midday on 31 July, 1938, Miss Barbara Dunn G6YL heard the hissing noise in the 5m band, confirmed by 2BIL, and Denis Heightman heard it again at 56MHz on 25 June, 1939.

Although amateur radio activity was suspended at the outbreak of war on 3 September, 1939, a few carried on listening, and the "hissing" was heard again during February, March and November, 1940 and March, June and July, 1941. The next known report about solar noise came in February 1942 when British radar receivers, working between 60 and 80MHz, suffered severe interference which contemporary scientists attributed to a large group of sunspots. Also in 1942, American scientists discovered radio noise in the microwave part of the spectrum coming from what is called the "quiet" sun.

Since the war, many radio observatories have studied the sun at a variety of radio frequencies, and it is now known that when sunspots are present (Fig. 4) the sun is said to be "active". Then, depending on the type of activity, solar radio noise will be heard, at varying degrees, between 30 and 300MHz with a peak in the 130-170MHz range.

Practical Observation

During the mid-1930s, several astronomers gave the 28MHz propagation group information about the sun, derived from their visual observations. With the discovery of the "hissing" noise in 1935, group members showed that they could observe the sun by radio, which was unaffected by overcast skies. The pre-war journals described Heightman's discovery as "The 'Hissing' phenomenon", which we often hear today in the 2m band when the sun is "active".

Through years of concentrated effort by both optical and radio astronomers, we now know that when great eruptions occur on the sun, vast amounts of nuclear waste are ejected, along with streams of particles. These may strike the earth's atmosphere some 20-40 hours later, disturbing the ionosphere and h.f. communications, or causing an aurora to manifest, with consequent risk of disruption to our v.h.f. signals. Radio provides an early warning of these events, because, when a solar eruption takes place, it emits radio waves which arrive here in 8·3 minutes, sounding like a "whooooooosh", or hissing, above the receiver background noise.

The Spectrohelioscope

Some years ago, Cmdr Henry Hatfield, Sevenoaks, built a complex optical instrument called a spectrohelioscope, Fig. 5 (see page 934, *PW* April 1978), to study the sun's surface. Henry uses this instrument, when the skies are clear, in conjunction with his 136 and 1296MHz radio telescopes and can often see the active area, such as a flare or filament, within a sunspot group (see page 65, *PW* May, 1978), which is causing the prevailing radio noise.

Some Spectacular Events

In July 1974, I had an 8-element Yagi directed towards the sun and feeding a 136MHz receiver, another system with a 3-element beam facing north-east on 70MHz, a vertical dipole connected to a set monitoring the R1 TV channel, 49·75MHz, and a long wire aerial feeding the 10m beacon monitor. Suddenly, one morning, a massive solar flare occurred and I heard the noise sweep across the frequencies and get stronger. Being inquisitive, I used the h.f. receiver to follow the noise, and found that it overpowered all signals down to 8MHz for about six minutes and then gradually faded away back up to 136MHz.

Early in August 1972, the static discharges from a local thunderstorm were frequently causing large spikes to be drawn on the chart of my radio telescope. Then, suddenly, a large burst of radio noise from the sun, 93 million miles

Fig. 5: Cmdr Hatfield adjusting the mirror of his spectrohelioscope which gathers the sun's light and transmits it to a second mirror housed in the building at bottom right. It then passes through an electrically-adjusted lens under the shingle cover (bottom left) to more complicated equipment in his observatory

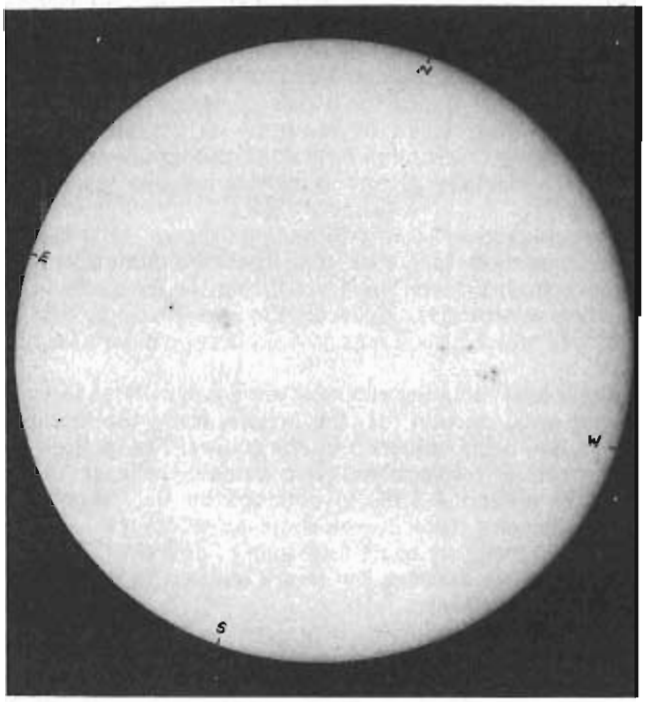

Fig. 6: Two groups of sunspots photographed by Cmdr Henry Hatfield on 7 August, 1975

away, overpowered the local static from 90 to 200MHz, for some eight minutes. This massive burst was the forerunner of a very big solar storm which occurred two days later, upsetting the ionosphere and creating one of the most extensive auroras for many years, visible as far south as Spain. The effect on v.h.f. was amazing; one amateur told me: "It was like an umbrella, Tone-A signals were coming from all directions."

Although sunspots (Fig. 6) are stationary, they appear to travel across the sun's disc due to its 27-day rotational period.This makes it possible for a very large sunspot group to re-appear for a second and third time, and it's not uncommon for a sunspot to be active when it appears on the east limb and remain so until it turns the corner on the western limb, some 13 days later. A typical example of this was the solar event which began with a few small bursts of radio noise on 6 September, 1974, developed into a severe radio noise storm lasting several days, and ended on the 19th. During the event there were many individual bursts lasting from 1 to 16 minutes, covering from 50-150MHz. All this resulted in an extensive aurora on the 15th and frequent reports by the BBC World Service about ionospheric disturbances affecting their long-distance signal paths.

The Unexpected

Patience is a dominating factor in solar observation. Many days, and sometimes weeks, can pass by with nothing more than a receiver noise trace on the recording chart. Then, suddenly, there it is—solar noise, and you have the first warning of an aurora or ionospherie disturbance which means DX by Tone-A for the v.h.f. enthusiast, and (most likely) dead bands for the h.f. operator.

Whatever happens, it is important that we amateurs record our observations for posterity just as methodically as our predecessors did, more than forty years ago. ●

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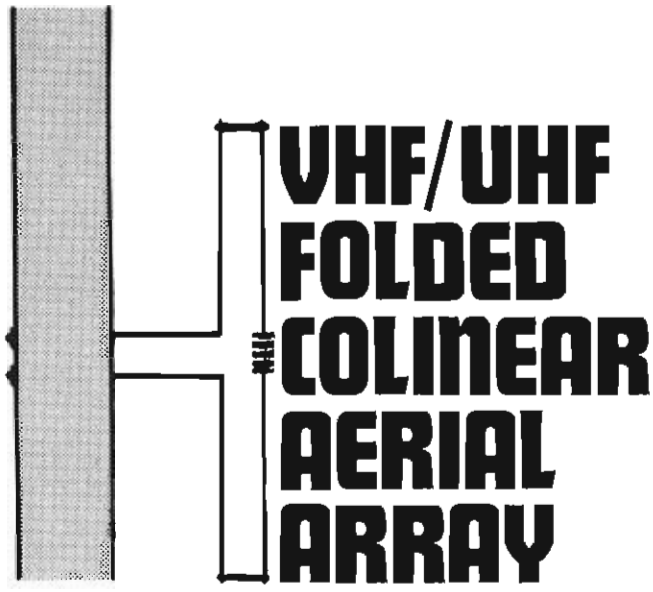


VHF/UHF FOLDED COLINEAR AERIAL ARRAY

Fred JUDD G2BCX

This aerial is a two-element colinear design for vertically polarised (omni-directional) radiation. It may be constructed for use on either the 2m or 70cm amateur bands and is a development of the very successful "Slim Jim", published in April 1978.

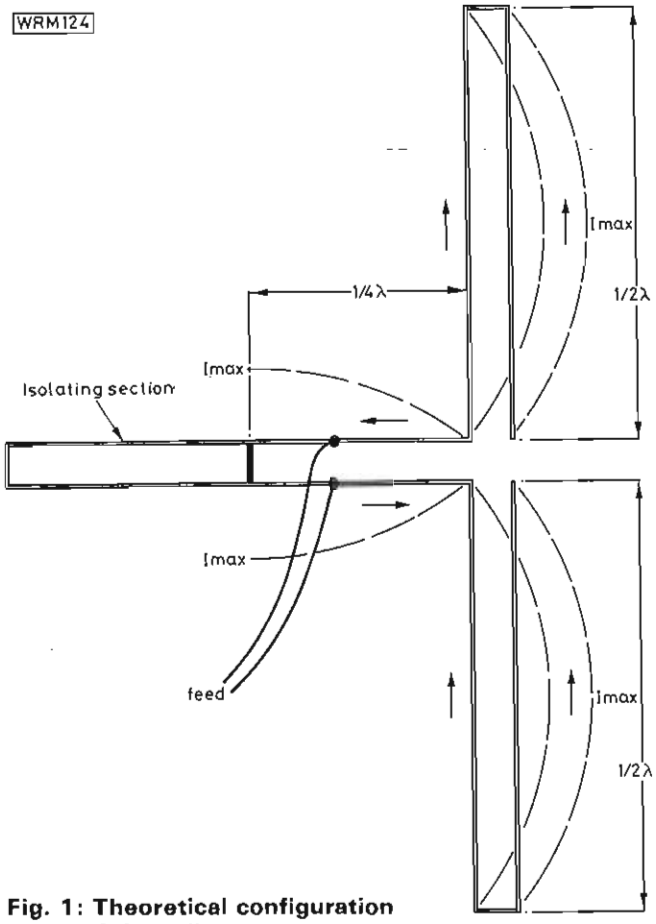


Fig. 1: Theoretical configuration of the colinear array

Two folded half-wave elements driven in phase from a quarter-wave stub constitute the active parts of the device, originally built for use on the Norwich 70cm repeater. The requirement called for a pair of aerials with at least 3dB gain which could be mounted on a mast without undue effect on their omni-directional properties—i.e. with minimal distortion of the otherwise circular radiation pattern.

The theoretical configuration is shown in Fig. 1. Experimentation indicated that the minimum tolerable distance from a metal mast producing the least effect on radiation was 0·625λ. Accordingly, a long stub section is employed which also serves as a supporting mount for the aerial.

The folded radiating elements are voltage driven from a quarter-wave section of the whole stub, the current distribution being indicated by the arrows. The increase in gain over a conventional two-element colinear (gain normally around 1·8dB) is obtained by the use of the folded elements, which contribute an additional 1·6dB. This aerial therefore has a total gain of 3dB over a dipole. Note the break between the return sections, necessary to create a standing wave.

Construction

The diagram of Fig. 2 should provide enough information to enable this aerial to be constructed for either 70cm or 2m, detailed dimensions being given in Table 1. For u.h.f. the aerial will self-support but for v.h.f. some form of boom at right-angles to the mast may be necessary to take the weight of the stub and elements—which are, of course appreciably longer than their u.h.f. counterparts. This could be constructed from wood, and reach at least as far as the quarter-wave section shorting bar. An alternative would be the use of larger diameter tubing for the elements and stubs, say 12·7mm ($\frac{1}{2}$in).

Connections to the feed point must be protected from rain and the prototype used an oblong plastic box with tight-fitting lid for this purpose. The insulator linking the two folded element sections should be of high quality material, such as ptfe, which is drilled to fit over the ends.

A piece of aluminium about 10mm square may be used for the quarter-wave shorting bar, drilled to take the stub lines and tapped for the 4BA screws which lock the bar to the lines. Element dimensions are given for both versions, the velocity factor having been taken into account.

Adjustment

When the aerial has been completed it should be set up in fairly clear surroundings, approximately 2 metres above ground, with the full length of feeder cable attached. Adjust the feed tapping points and quarter-wave point (shorting bar) for maximum power and v.s.w.r. All v.h.f. aerials operate most efficiently when high up and clear of rooftops or other obstacles, such as tall trees. This is particularly true in the case of colinears with zero-angle radiation. Sizeable trees in full leaf can attenuate v.h.f. and u.h.f. signals by as much as 20dB when placed in the path of radiation, even in dry weather. Brickwork can reduce signals by 10dB or more.

The vertical angle polar pattern of Fig. 3 was taken from the Author's display unit and clearly shows the radiation characteristics of the u.h.f. prototype.

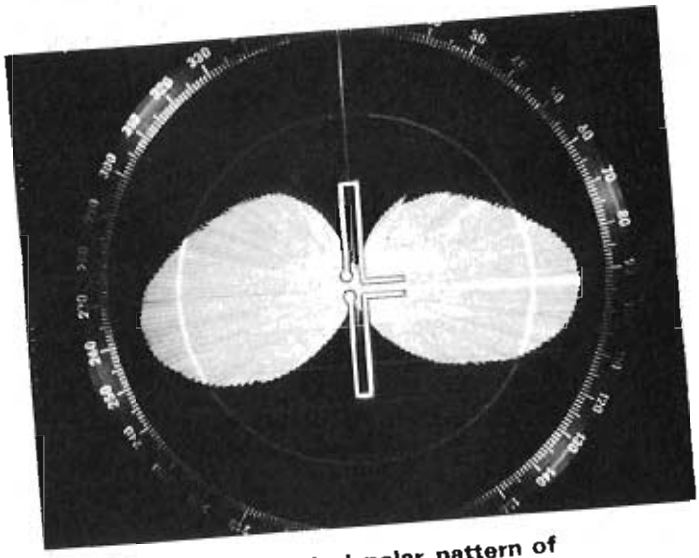
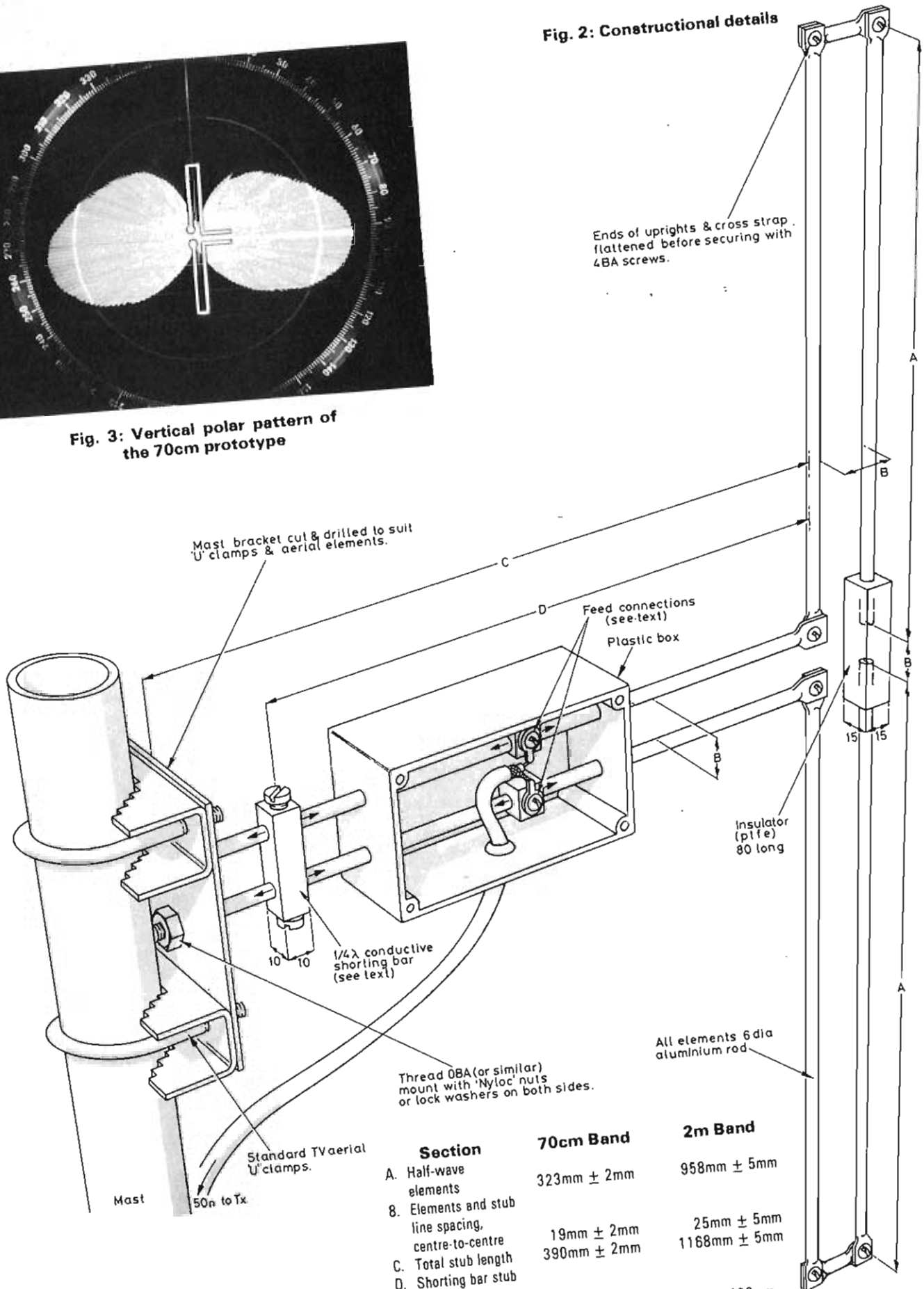


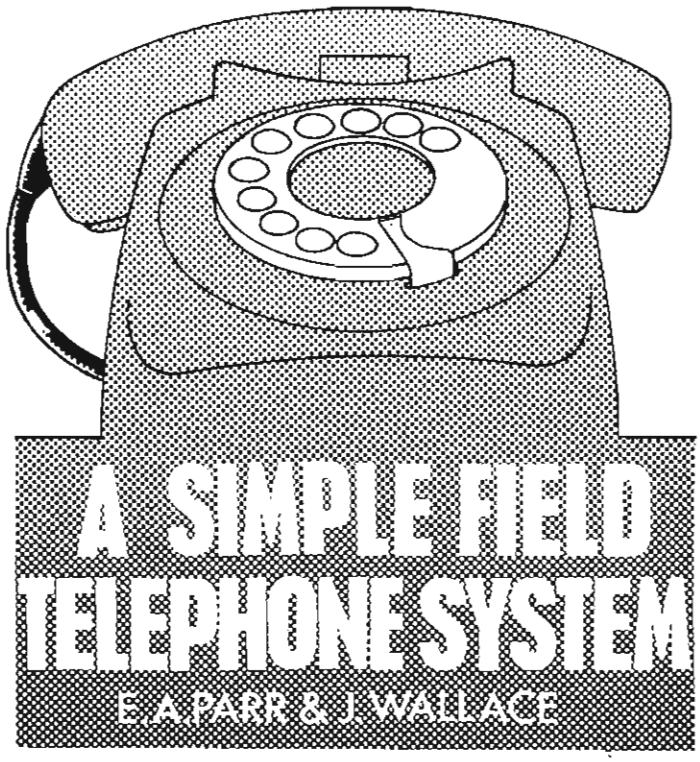
Fig. 3: Vertical polar pattern of the 70cm prototype

Fig. 2: Constructional details



Section	70cm Band	2m Band
A. Half-wave elements	323mm ± 2mm	958mm ± 5mm
B. Elements and stub line spacing, centre-to-centre	19mm ± 2mm	25mm ± 5mm
C. Total stub length	390mm ± 2mm	1168mm ± 5mm
D. Shorting bar stub section, from junction of driven elements	Approx 175mm (see text)	Approx 469mm (see text)

All dims in mm.



The authors spend a large amount of their working year on site, commissioning complex electrical equipment. This often involves checking electrical panels several hundred yards from control panels and the work is usually hindered by poor or non-existent communications.

The simple telephone handset system described here was developed to provide versatile instant communications. To meet our requirements, the system must:

1. Be cheap. Despite million-pound budgets for projects, firms usually baulk at a £10 order to RS Components.
2. Be battery-operated with a very long life on a PP3 battery.
3. Comprise, at each end, a telephone handset (or headset with a boom microphone) and an amplifier. The amplifier must be small and light enough to be carried in a pocket.
4. Unlike the usual "baby alarm" circuit, have two-way speech with no press-to-talk buttons.
5. Be a two-wire system, floating to allow use with spare cores in multicore cables shared with high-voltage, heavy-current signals without suffering from interference.
6. Have a call facility which will work with the receiving amplifier turned off.
7. Have a range of approximately 1 km.

These design criteria were met by a simple circuit built around standard Post Office-style handsets and the ubiquitous 741 amplifier.

Circuit Description

The basic design is shown on Fig. 1. We have two handsets and amplifiers, denoted A and B, connected by a signal pair. Each amplifier is connected to the signal line by a series resistor RSA and RSB. The two earpieces are connected direct onto the lines.

Suppose amplifier A is transmitting, and we have a voltage V_{OA} at the amplifier output. Since the output of amplifier B looks like a low impedance, the voltage on the line will be

$$V_{LA} = V_{OA} \times \frac{\text{(RSB in parallel with two earpieces)}}{\text{(RSB in parallel with two earpieces)} + \text{RSA}}$$

Similarly the voltage on the line from amplifier B will be:

$$V_{LB} = V_{OB} \times \frac{\text{(RSA in parallel with two earpieces)}}{\text{(RSA in parallel with two earpieces)} + \text{RSB}}$$

Since $V_{OB} = V_{OA}$ by design and RSA = RSB by design then $V_{LA} = V_{LB}$ and speech of equal volume will be obtained in both earpieces, and two-way speech is possible. Note that when you speak into your handset, you will hear yourself in your own earpiece. This effect, known as sidetone, is deliberate, as it is disconcerting NOT to hear yourself, and in addition it reduces the natural tendency to shout in noisy locations.

The actual circuit of one handset and amplifier is shown in Fig. 2. The circuit of the other amplifier and handset is, of course, identical. The microphone in a standard PO handset is a carbon transmitter, and needs a bias current. This is provided by R1. In the absence of any data, the value of R1 was determined empirically. IC1 is a conventional 741 op. amp. connected as an inverting amplifier. The amplifier is biased by R2 and R3 to a point mid-way between the supply rails. The signal from the microphone is a.c. coupled to the amplifier and the gain of the amplifier is fixed by R4 and R5. This was deliberately made non-adjustable to ensure that V_{OA} and V_{OB} are equal. If moving-coil microphones are used, R4 and R5 may need to be changed, and R1 may be omitted. At the amplifier output, a signal of approximately 1 volt is produced. The amplifier output is a.c. coupled onto the line via C2. Resistor R6 is the source resistance RS of the amplifier mentioned above.

The earpiece is connected to the line via the volume control VR1. Note that this only affects the received volume, not the transmitted volume. In theory it will affect the volume on both earpieces as the load on the line is changed, but this effect is negligible.

The call facility is provided by S2. This simply applies positive feedback via C3, causing IC1 to oscillate. As a practical observation it is advisable to remove the handset from your ear before pressing the call tone button. If the circuit is used with earphones and a boom microphone, the call facility is best omitted in the interest of preventing induced deafness!

The ON/OFF switch is a two-pole switch. One contact switches the supply, the other causes the earpiece to bypass the volume control so that the call facility can be used when the receiving amplifier is turned off and the volume control is turned right down. When in use, battery consumption is a miserly 1-2 mA.

Construction and Use

The amplifiers were built on a piece of 0·1 in pitch Veroboard measuring 42 × 42 mm, with the layout shown on Fig. 3. The circuit board, volume control, ON/OFF switch, line connector and battery were mounted into a standard diecast box which is small and light enough to fit into a pocket.

The circuit is so simple it should be straightforward to fault-find on if problems are encountered. An obvious area to start is the voltages on pins 2, 3 and 6 of IC1. These should all be at half battery volts. To aid fault finding and repairs, IC1 should be mounted in a d.i.l. socket.

The connection to the line is made via a jack plug and socket or crocodile clips, as convenient. It is important that neither of the signal lines is connected to the case. There are two reasons for this; the first being safety. In impromptu use it is quite possible that a live wire could be used in error: with a signal wire connected to the case the

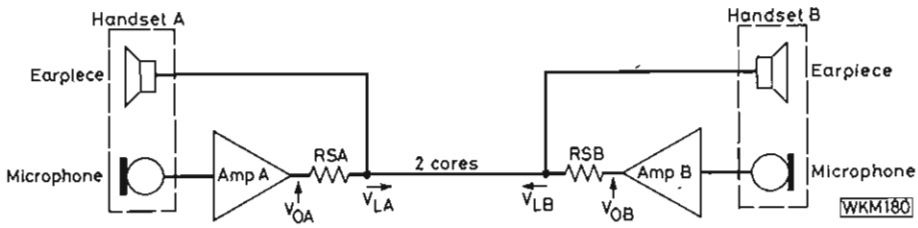


Fig. 1: Basic principles of two-way operation

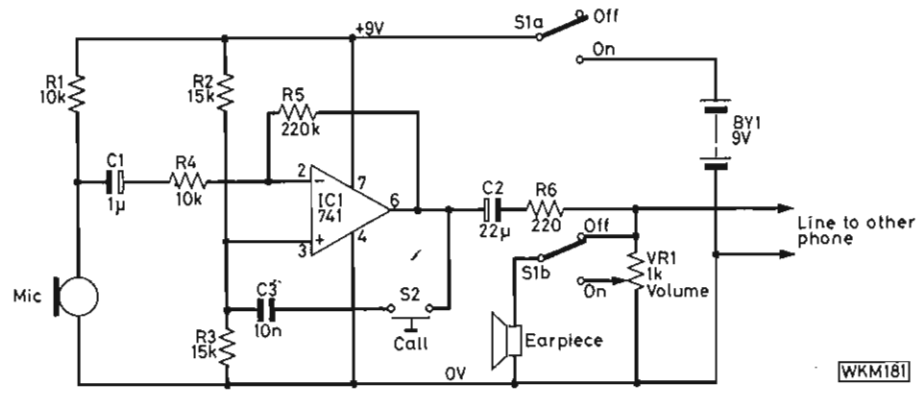


Fig. 2: Circuit diagram of one telephone

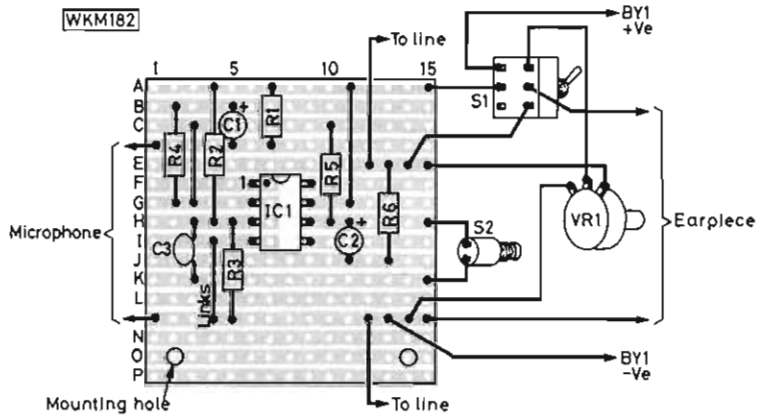


Fig. 3: Veroboard layout and external connections. The only track cuts required are those beneath IC1

★ components

THIS LIST COVERS ONE AMPLIFIER AND HANDSET

Resistors

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220Ω	1	R6
10kΩ	2	R1, 4
15kΩ	2	R2, 3
220kΩ	1	R5

Potentiometers

1kΩ	1	VR1

Integrated Circuits

741	1	IC1 (8-pin d.i.l. version)

Capacitors

Disc ceramic

10nF	1	C3

Tantalum bead, 16/35V

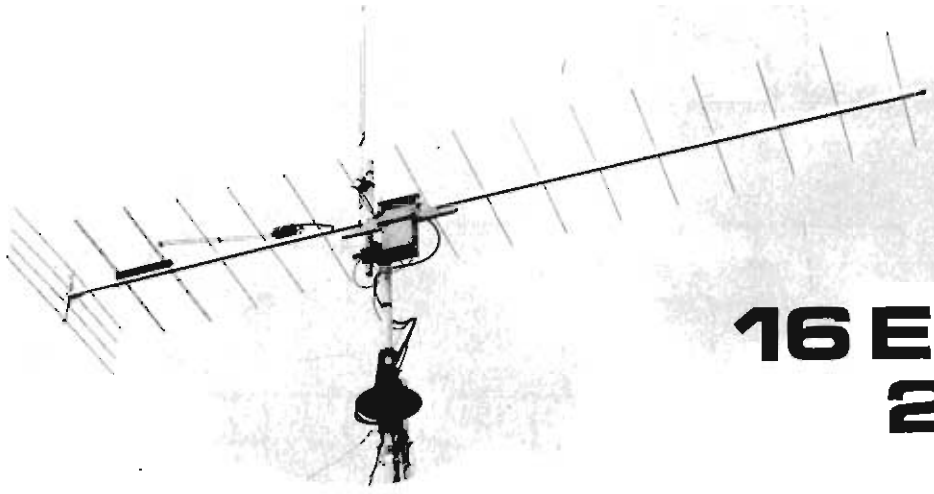
1µF	1	C1
22µF	1	C2

Miscellaneous

S1 Min. toggle d.p.d.t.
S2 Min. push-to-make
Veroboard 0·1 in pitch, 42 x 42mm
8-pin d.i.l. socket (optional but recommended)
Diecast box 114 x 64 x 30mm. PP3 battery and connector. Post Office-style handset and cable (available from surplus shops, etc.). Jack plug and socket, or crocodile clips (see text)

results could be fatal. The second reason is that if the signal wires were crossed, and both cases were on an earthed surface, the signal would be shorted and the phones would not work.

Several pairs of phones have been constructed, and they have proved to be a valuable aid to site work. They have been operated in adverse conditions with high background noise and in the presence of electrical interference and have proved very durable. Apart from the obvious industrial use they were designed for, they are also useful for applications such as sports meetings, amateur dramatics, aerial adjustment, house to shed links etc. The simplicity and low cost makes them an excellent project for an inexperienced constructor. ●



'2BCX 16 ELEMENT 2m BEAM

F. C. JUDD G2BCX

High-gain beam aerials of the conventional Yagi type for 2-metre operation are of necessity rather long, the average being 5 to 6 metres to achieve a gain of more than about 14dBd (dB relative to a dipole). The alternative way of obtaining high gain would be a pair of beams of smaller dimensions which, suitably phased, should (in theory) provide an increase in gain of 3dB over that of one by itself. Unfortunately this rarely works out in practice, and the extra gain is usually somewhat less than 3dB.

In fact, the possibility of using a suitably matched and phased pair of 12-element ZL beams (designed by the writer and published in *PW* November 1978) was considered, since this aerial is physically smaller (3·2m) than a normal Yagi type having the same gain of 13dB. However, this would have involved double the amount of material required for a single aerial (and thus twice the cost) and a spacing between the pair of at least 0·75λ (almost 2m) in order to achieve anything approaching the extra 3dB gain. Such an array would present a rather large total area to the wind. Neither did the 12-element ZL lend itself to achieving higher gain by simply adding more directors, at least not without extensive modification and increasing the length considerably.

A gain of 3dB over the existing gain of an aerial may not seem worth while, but it does in fact mean twice the original radiated power. For example, with an aerial such as the 12-element ZL having a gain of 13dB and radiating all of, say, 10 watts applied to it, the effective radiated power (e.r.p.) would be almost 200 watts. Another 3dB would mean an e.r.p. of nearly 400 watts!

Taking into account all of the foregoing observations, it was decided to investigate the possibilities of a beam aerial that would provide at least 16dBd total gain, be not unduly long, not too expensive to construct, be of reasonably light weight and not present too much area to the wind.

The '2BCX 16-Element Beam

The basis of this aerial is a double driven element and plane reflector system, designed to provide the highest possible initial gain. The driven elements are a pair of folded dipoles, coupled by a short crossed transmission line so as to obtain current in one element in phase opposition to that in the other, i.e., they are driven with 180° phase difference. Such a system is commonly called an end-fire array (Ref. 1) which with close spacing between the elements (approx. $\frac{1}{8}\lambda$) provides the highest gain possible (nearly 4dB) with any driven linear pair (Ref. 2). The configuration of such an array and its radiation pattern compared with that from a dipole are shown in Fig. 1.

We now have a driven element system with a relatively broad bandwidth, by virtue of the folded dipoles, and a large amount of radiation in two directions which allows the use of a reflector as well as a series of directors. The self impedance of this type of array is, however, only a few ohms and this becomes even less when parasitic elements are in close proximity. Hence the use of a half-wave line section to secure a direct match to 50 ohm coaxial cable.

Details of the whole aerial are given in Fig. 2, which includes all radiator lengths, etc., but not those of the plane reflector elements, the phasing line and the matching line sections. Details for these are included in other diagrams. The total length of the aerial is 4·26m and it has a measured gain of 16dBd. Three prototypes were constructed and tested, and the final version as described here has been in use for almost a year at a height of about 25 feet above ground and 70 feet a.s.l. Distances of 100 miles and over have been worked consistently on 2 metres f.m. regardless of conditions, and large numbers of continental stations (in France, Belgium, Holland and Germany) have been worked direct with average signal reports of well over S9 during only medium "lift" conditions.

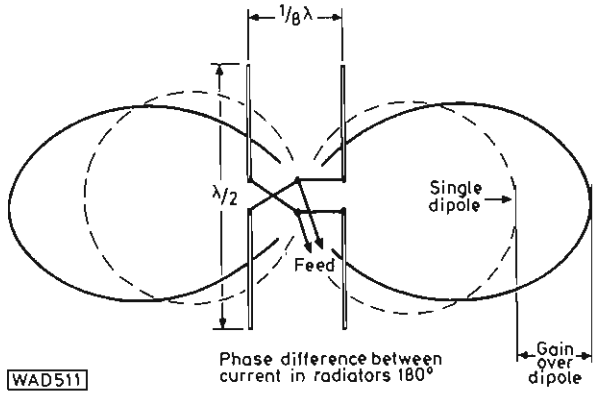


Fig. 1: Function of the two half-wave driven radiators with currents 180 degrees out of phase

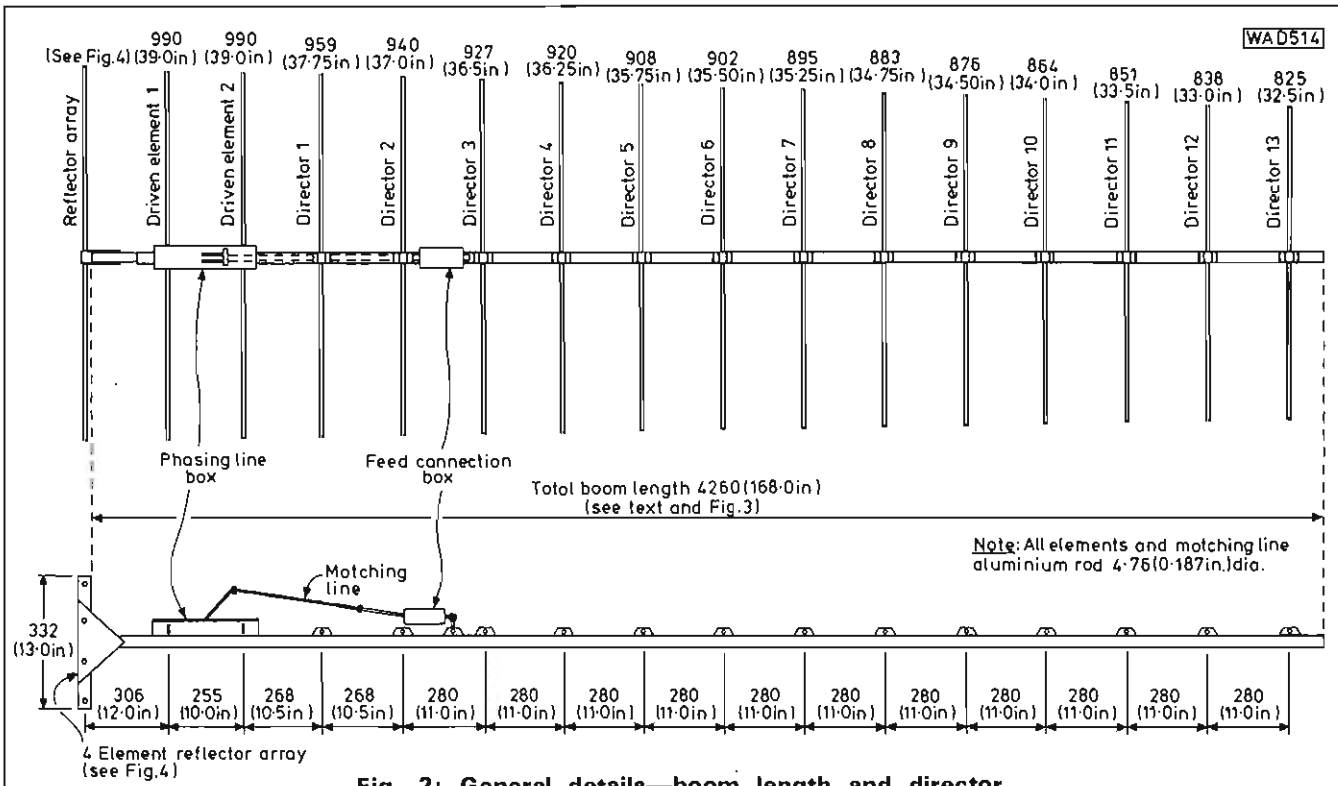


Fig. 2: General details—boom length and director lengths and spacing, etc. See also Figs. 4 and 5 for assembly of reflector and matching line

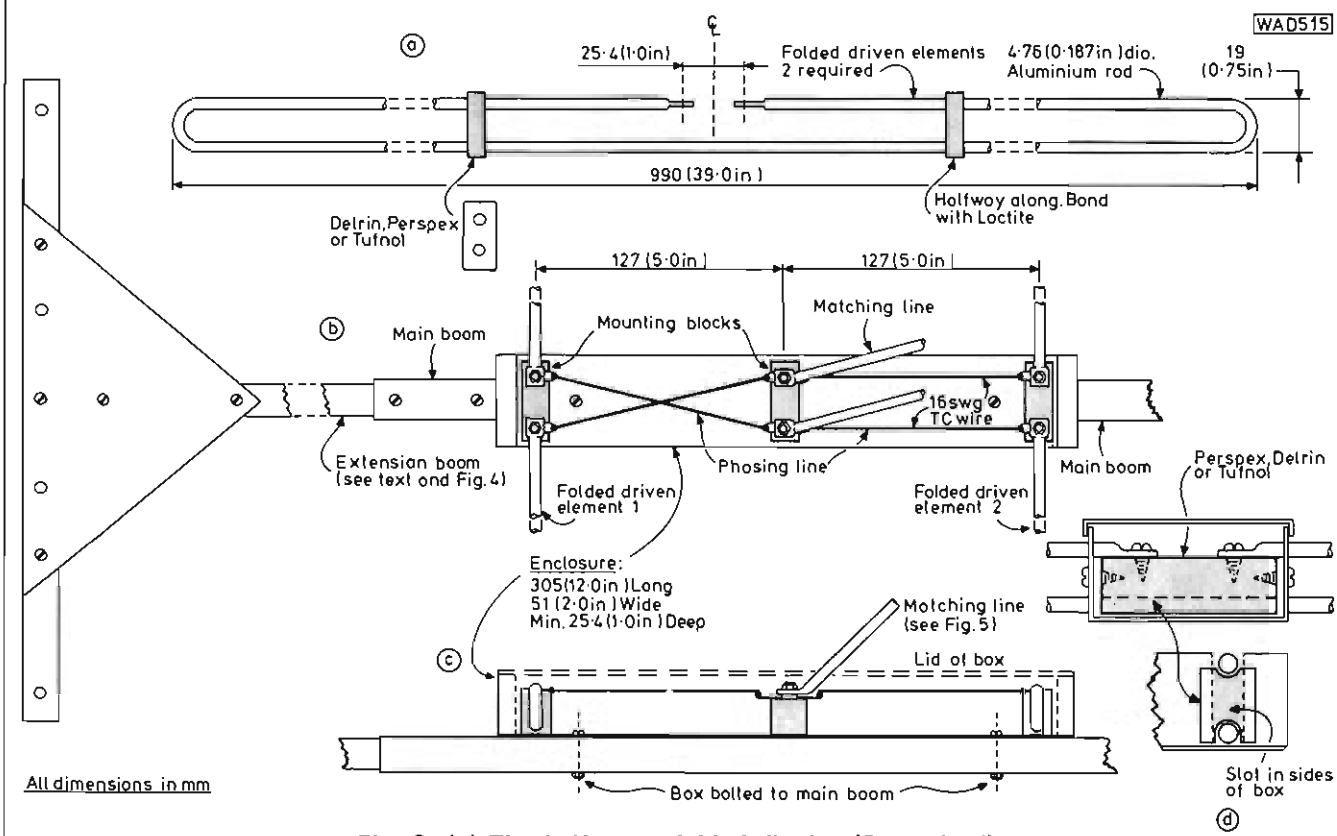


Fig. 3: (a) The half-wave folded dipoles (2 required). (b) Phasing line and dipole connections—top view. (c) Side view—box bolted directly to boom. (d) Suggested method of securing dipoles within box

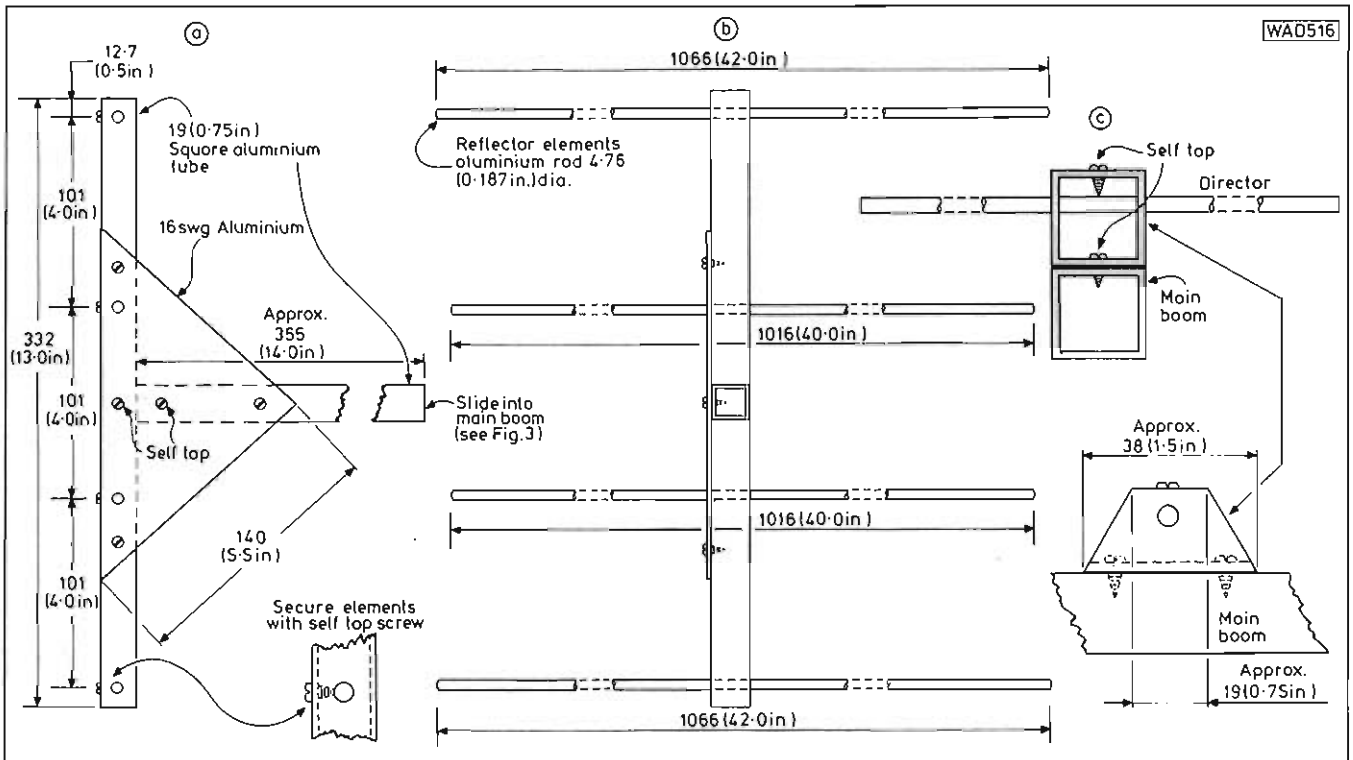


Fig. 4: (a) Side view—assembly of plane reflector. (b) Reflector details. (c) Method of securing directors to main boom

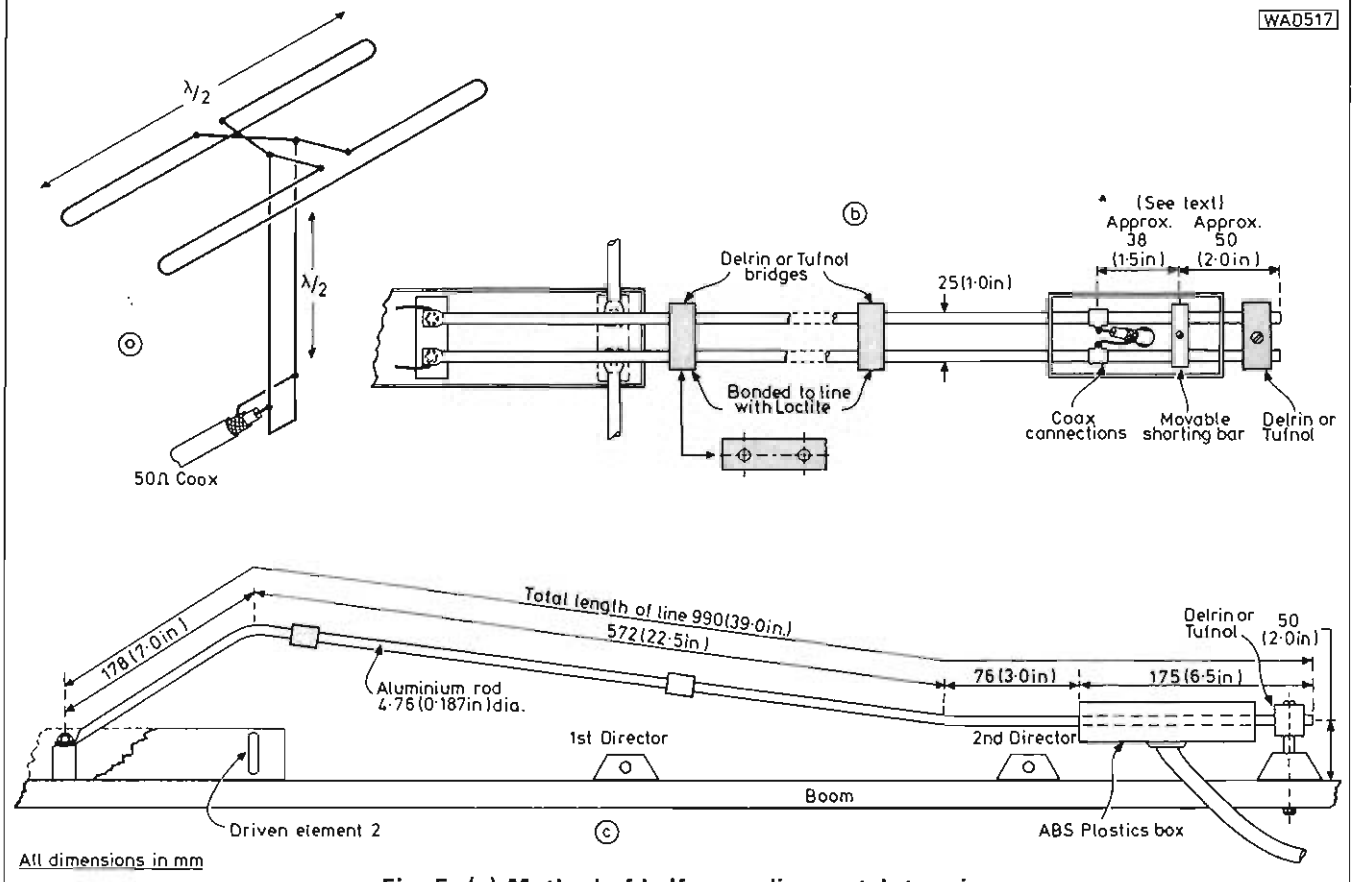


Fig. 5: (a) Method of half-wave line match to primary radiators. (b) Top view of matching line assembly. (c) Side view

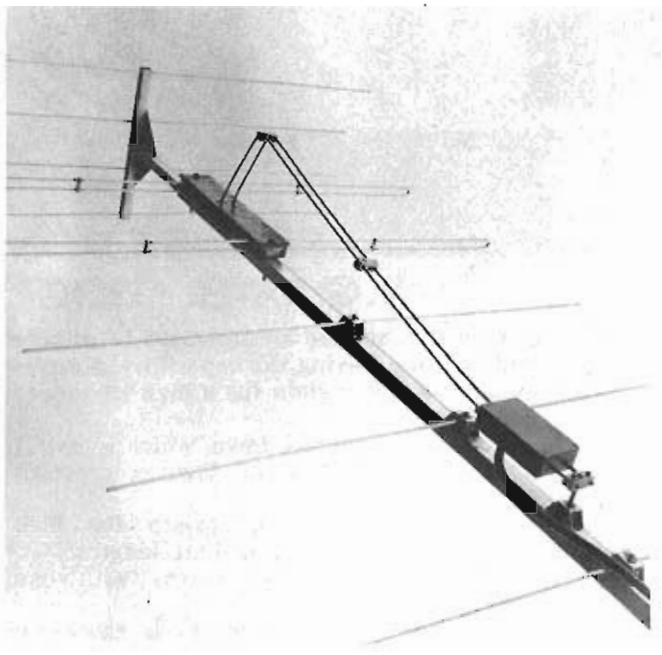


Fig. 6: Photo of phasing line box, matching line and coaxial connecting box

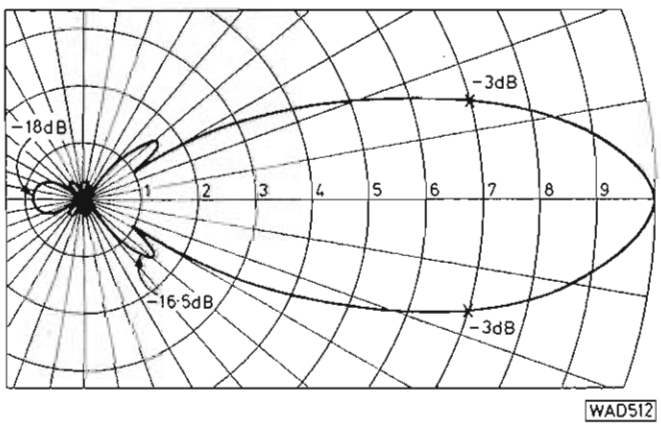


Fig. 7: Radiation pattern in horizontal mode under ideal test conditions

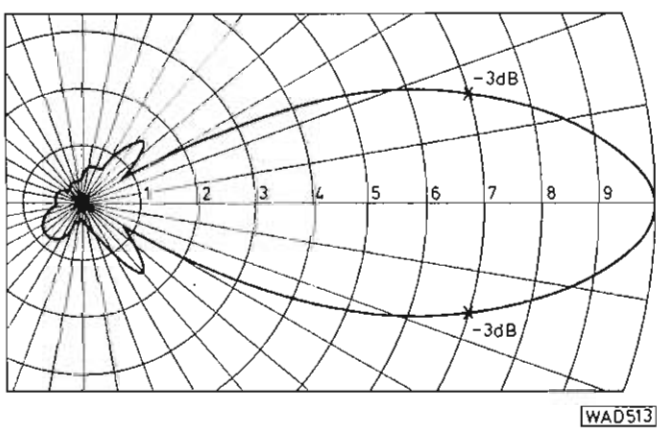


Fig. 8: Radiation pattern in horizontal mode with aerial in normal environment (see text)

Construction

All details for construction as for the prototype shown in the photo, are included in the various diagrams. It is important to maintain good insulation at the driven element and phasing line junctions, and along the matching line and at its feed point, and also to ensure that water cannot enter the phasing line and coaxial cable connection boxes.

The main boom is of 1in (25·4mm) square-section aluminium tube and this is usually sold in standard lengths of 4m. The plane reflector is therefore mounted on a short length of 0·75in (19mm) square section tube that will fit into the end of the main boom as in Figs. 3 and 4.

Construction of the two driven dipoles and assembly with the phasing line box is shown in Fig. 3. This box can be made from plastics electrical trunking, blocked at each end with Perspex or plywood about 10mm thick. The mounting blocks for the elements and phasing line may be Delrin, Tufnol, Perspex or PTFE. Note how the matching line is connected to the centre of the phasing line, so make entry holes for this in the lid of the box. The two driven elements can be "U" formed at each end by means of a round piece of metal or wood clamped in a vice. Heat the point where the "U" bend is to be made but bend slowly and gradually and don't overheat the aluminium. A trial on a scrap length is recommended. Remember however to put the element spacers on before the bends are made and thread these to the appropriate points before the connecting flats are hammered out and drilled.

Construction and assembly of the plane reflector is shown in Fig. 4. It consists of four elements to form the required plane area and the lengths of these are set to take velocity factor into account. Note also the method of securing the self-tapping screws (zinc plated) through the vertical boom, which is attached to the horizontal boom section by the triangular aluminium plate. Lengths and spacings for the 13 directors are given in Fig. 2 and these are mounted on the main boom by supports cut from 1in (25·4mm) square section tube as in Fig. 4(c).

The final part of construction is the half-wave matching line and coaxial line feed box as in Fig. 5, in which (a) shows the theoretical arrangement, (b) a view of the line from above and (c) from the side. The photo, Fig. 6, shows a close view of this assembly. Make the holes for the line just large enough for the coaxial feed box to move backward or forward to facilitate the setting of the shorting bar and the points of connection for the cable. When these have been established the box can be secured to the lines by Araldite.

Adjustment and performance

Setting the feed point and shorting bar positions are the only adjustments necessary, but must be carried out with the full length of coaxial cable to be used, preferably low-loss cable such as UR67. Set the aerial up at least 6 feet above ground and in a clear space. This will most likely be in the garden, and if the transmitter can be taken out near the aerial it will be much easier to watch the power or v.s.w.r. meter whilst adjustments are being made. Set the shorting bar and coaxial feed points as shown in Fig. 5(b). Adjust both one way or the other to obtain lowest v.s.w.r. or maximum power into the aerial at mid-band, i.e., 145MHz. It should be possible to get the v.s.w.r. down to 1·1 to 1·2 to 1 at mid-band, and this should rise only slightly at each end of the band.

Before the aerial is finally hoisted to the mast, make sure that the phasing line and coaxial connection boxes are

continued on page 36

AERIAL TUNER

F. G. RAYER G3OGR

This tuner can be used with end-fed or balanced feeder systems, either for reception or transmission. When used with a receiver, a substantial improvement in signal strength is obtainable. For transmission, it allows the usual pi-tank to be matched to end-fed, Zepp, and other aerials.

Construction

L1 is wound with 20 s.w.g. tinned copper wire, and L2 is of well-insulated wire, on top of L1, as in Fig. 2. The former is 89mm x 44mm and 34 turns are used in all. Taps are equally spaced at six turns, two turns, four turns, and five turns from the centre tap. They are made by passing short lengths of 16 s.w.g. wire into holes in the former, and securely

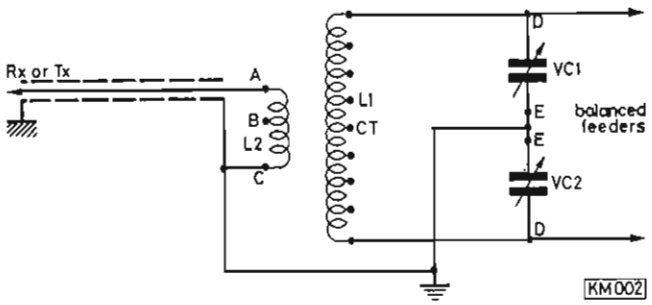


Fig. 1: The circuit diagram of the aerial tuner

soldering these to the winding turns as required. Nine 6BA bolts with tags, mounted on a piece of paxolin about 102mm x 102mm (as in Fig. 2), support the coil. Below these taps fit three bolts for A, B and C. A to B is three turns, and B to C has four turns, so that three, four, or seven turns may be selected. Two further bolts are for E, E, Fig. 2.

Provided plenty of taps are available, other coils may be suitable.

Methods of Coupling

It is possible to find a suitable coupling method by trial only, especially for reception alone. Fig. 3 will help clarify some of the more usual configurations.

"A" is a pi-coupler, and adjustment of the capacitors allows a wide range of impedances to be matched, either to load the transmitter correctly, or to give best reception.

"B" is a popular method for high impedance aerials. With a transmitter, a co-axial lead is generally used, with outer conductor to the chassis. This, shown at "B" may be fitted for any circuit.

"C" employs the link for coupling. For low frequencies, the two capacitors may be put in parallel as shown, and this is useful if they are not of very large value.

"D" is a somewhat similar arrangement to using a centre-tapped coil and having the capacitors in series in this way is most appropriate for a high frequency band.

"E" shows the aerial tapped down, which is useful with parallel tuning when aerial loading prevents proper tuning with "B".

"B", "C" and "D" are appropriate for high impedance. "E" suits many intermediate lengths. "F" is for low impedance (quarter wave) with one capacitor used for series tuning.

Parallel tuning of balanced feeders is shown in Fig. 1. This is satisfactory when the feeder termination is high impedance. For low impedance feeders, "G" in Fig. 3 is necessary. The best balanced system is a tuned doublet. The top is divided into equal lengths, and the twin feeders are spaced about 102mm by spreaders. High impedance feed is expected if one-half the top, plus the feeder, equals a half-wave or multiple of half-waves. Should one-half the top plus feeder be a quarter wave or odd multiple, low-impedance coupling "G" is anticipated.

★ components

VC1 and VC2 350pF Jackson 5021/2 or similar. Ceramic or paxolin former, 100 × 100mm. Aluminium base 165 × 100 × 9mm, aluminium panel 203 × 152mm, Case 203 × 152 × 152mm. Tinned copper and insulated wire.

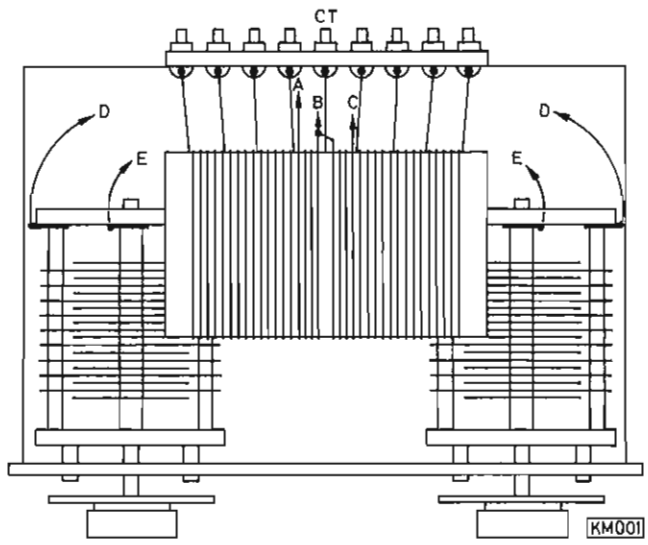
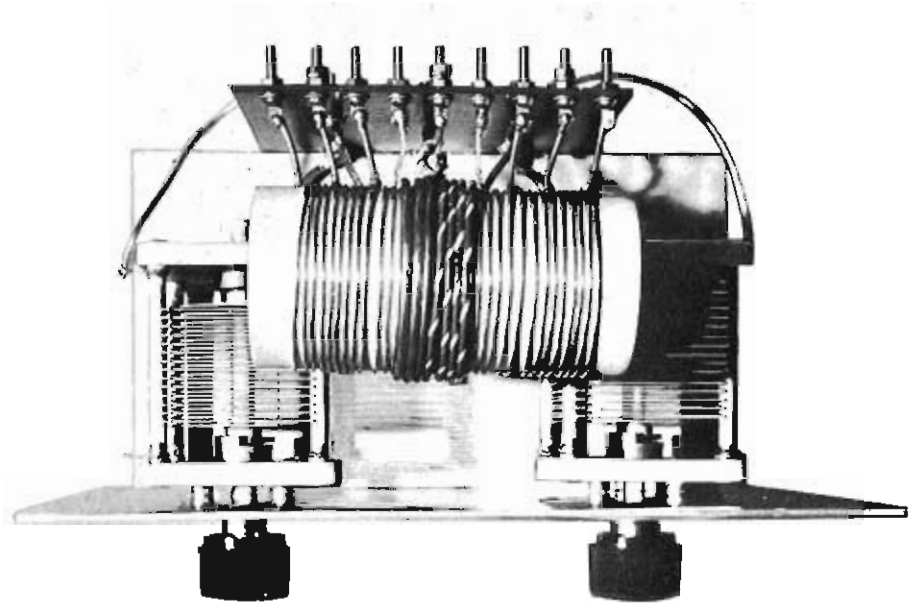


Fig. 2: General layout, showing connections to screw terminals



A view of the unit showing L2 (p.v.c. covered wire) wound *over* L1

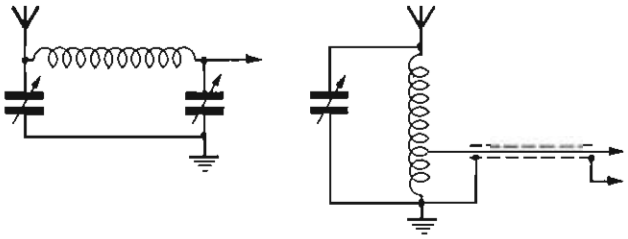


Fig. 3: Coupling circuits A and B

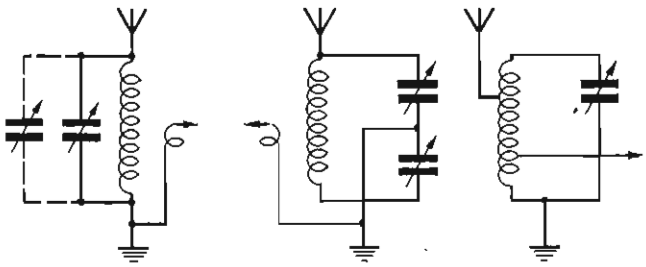


Fig. 4: Coupling circuits C to E

Frequency

Circuits showing the whole of L1 in use, above, are for the 80m band. For higher frequencies, fewer turns are used. With "A" short out unwanted turns. Circuits such as "B", "C", "E" and "F" are used at higher frequencies by moving the aerial and capacitor connections down the coil.

With balanced circuits, Fig. 1, "D" and "G" in Fig. 3, move taps in equally from each end.

There is sufficient latitude to allow tuning up for reception on 25m, 31m and other broadcast bands, if required.

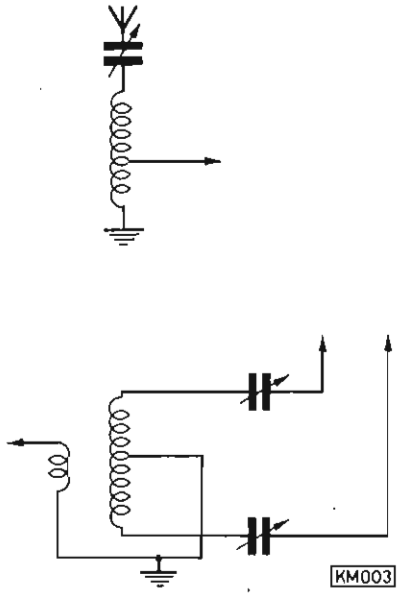


Fig. 5: Coupling circuits F (upper) and G (lower); details of all coupling circuits are given in the text

Reception

For reception purposes only, it is an easy matter to try various tappings or circuits, to find which peaks up signals best. This can be done with the aid of the S-meter, selecting a signal not subjected to fading. "B", "E" and "F" will cover most conditions likely to be met with a single wire aerial. The improvement is greatest when the original match with no tuner was poor.

Fig. 1 or "G" will be used with twin tuned feeders (doublet or Zepp) or Fig. 1 with feeders tapped in equally from each end of L1.

Transmission

The points already mentioned apply, plus the fact that for correct operation and loading, suitable matching is essential. Mis-matching may in fact cause damage to the transmitter output stage.

An excellent method of matching is to place a standing wave indicator in the co-axial lead from tuner to transmitter, and adjust the tuner for minimum SWR, with reduced power. An indication of 1·5:1 or lower is normally satisfactory. Adjustment to a very low SWR (virtually 1:1) is generally simplified by placing a variable capacitor in series with the link or tap—e.g., between A and the co-axial inner conductor in Fig. 1. A 500pF component is suitable for h.f. bands, and 2×500pF for 80m, receiver type capacitors having adequate spacing. "A" Fig. 3 does not require this item, and can generally provide virtually 1:1 SWR.

Capacitor settings and tappings used for each band should be noted so that re-tuning is possible with a minimum of trouble. ●

The Path of the WAVES

R.A.HAM

The propagation of radio waves is extremely complicated and many highly technical books and papers, resulting from far-reaching and sophisticated research, are available from public libraries and book sellers. The prime object of this article is to outline the many aspects of the subject and to encourage readers to make a more in-depth study of the paths of radio waves in their particular field of operation, because a better understanding of this can prove very rewarding when hunting for DX.

The Home Station

Apart from the sheer enjoyment of using the short-wave bands, the scientific aspect of a DX signal is as exciting to the enthusiastic tuning his receiver, as it is to the operator transmitter. Although a great deal is already known about the strange behaviour of radio signals when parts of the Earth's atmosphere are disturbed, there is still a lot to learn and the observations made during each new event and published in our technical journals, will be of value to the scientists of the future.

Before equipping the home station, the operator, whether a licensed amateur, broadcast or short-wave listener, radio-astonomer, satellite enthusiast or TV DXer, must decide first where to locate his "shack" and then where to locate his aerials. Ideally these should be as close to the equipment as possible to avoid unnecessarily long and therefore lossy feeders. The choice and size of aerial, described elsewhere in this publication, depends on the band being used and the space available (Fig. 1). Following years of research, it is now well known that radio waves generated on this planet, and those approaching it from outside, must travel through the atmosphere and, depending upon their wavelength, their paths are mainly influenced by two major regions: the ionosphere and the troposphere (Fig. 2).

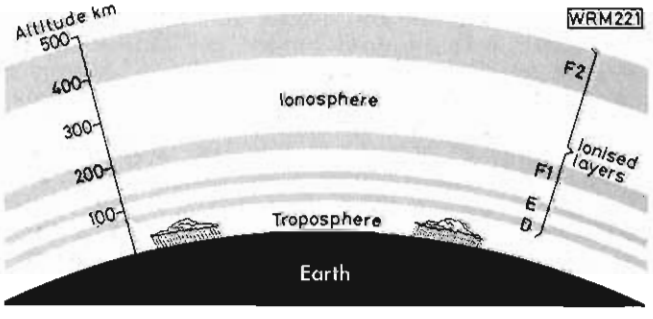


Fig. 2: Approximate boundaries of the various layers of the Earth's atmosphere

Fig. 1: On top of the 70ft tower belonging to John Tye G4BYV, Dereham, Norfolk is a 13-element Yagi for 70cm, 4ft dishes for 23, 13 and 9cm, and an 8-element Yagi for 2m

Signals from Outside

Although the nearest star to Earth, excluding the sun, is only 4:3 light years away, it is still too far for detailed study. Therefore, through consistent observations of the sun, a mere 93 million miles from Earth, astronomers have learnt a great deal about general stellar behaviour. Like most other stars, our sun is a nuclear furnace; it has a core temperature of 15 million degrees and a diameter of approximately 864 000 miles.

Periodically, dark patches, called sunspots (see *The Sun's Influence,* elsewhere in this publication) appear on the sun's disc. Some are very small and have a short life while others are large, often in groups, and may survive for several rotations of the sun. It has been known for about 45 years, that when sunspots are present, solar flares are likely to occur, ejecting streams of particles into the solar system and emitting strong bursts of radio noise, (Fig. 3) which can be heard between about 120 and 220MHz. Under these conditions the sun is said to be "active". Prospective radio-astronomers should find about 500kHz within this range that is clear of terrestrial signals before making radio observations of the sun. Radio waves from the "quiet" sun, mainly thermal in origin, can be detected between 100 and

10000MHz, gaining in strength as the frequency increases. Microwave enthusiasts sometimes compare the radio noise from the "quiet" sun with the cold sky to calibrate and test the sensitivity of their aerials and receivers.

The ultraviolet radiation from the sun is also very strong and has considerable influence over the structure of the ionosphere.

The Ionosphere

The existence of the ionosphere was not fully appreciated until the advent and development of radio communications in this century. Around the time that Marconi sent the first wireless signal across the Atlantic Ocean in December 1901, Oliver Heaviside in England and Arthur Kennelly in the USA suggested that a natural reflector of radio signals existed in the upper atmosphere, but it was Professor (later Sir) Edward Appleton who showed that an ionised structure existed in four basic layers and, what's more (DXers take note) he proved that the amount of ionisation in each layer depends on the time of day, season of the year and the amount of sunspot activity.

At one time the lower ionosphere was named, Kennelly-Heaviside and the upper part, Appleton, to honour these scientists, but now the ionospheric regions are simply identified as D, E, F1 and F2. It is generally accepted that the ionosphere begins with the D layer, some 40 miles above Earth's surface, and ends with the upper F2 layer approximately 160 miles higher. The majority of DXers who operate on bands between 14 and 60MHz are mainly concerned with the E region, especially during the mid-summer months.

Sporadic-E

The ultraviolet radiation from the sun causes the E layer of the ionosphere, some 60 miles above the Earth, to form at sunrise and disperse at sunset, but, for some unknown reason, during the period of May to August, this layer will, without warning, suddenly break up into clouds of more densely ionised gas. Then, for several hours, this disturbance will play havoc with terrestrial radio signals between 30 and 80MHz and in extreme cases can spread to 150MHz. Under these conditions, known as sporadic-E, radio and television signals, which have a normal range of about 100 miles, can easily travel for more than 1000 miles.

After many years of monitoring the television synchronising pulses on Channel R1, 49.75MHz, during the sporadic-E season, the author found that, in southern England and possibly elsewhere in the UK, this is the first signal to be heard at the beginning of a sporadic-E event and the last to fade away at the end. These events may occur two or three times per day or perhaps miss a few days during the season. On some occasions the disturbance is limited to between 30 and 50MHz, or to the higher range, 50-80MHz, but whatever happens, it seems that 50MHz is the most vulnerable. Radio amateurs who use the 4m band, 70.025-70.7MHz, frequently hear very strong f.m. signals from broadcast stations, mainly Polish, when sporadic-E is present. This is because several eastern-European countries use the range 65-73MHz for their national broadcasting. Although these signals are unlikely to be heard in the UK under normal conditions, they are sometimes also heard during an auroral manifestation or via meteor trial reflection. During the 1979 season, sporadic-E disturbances occurred on approximately 48 out of the 95 days between May 19 and August 21 and, as in previous years, most of the disturbances lasted for several hours.

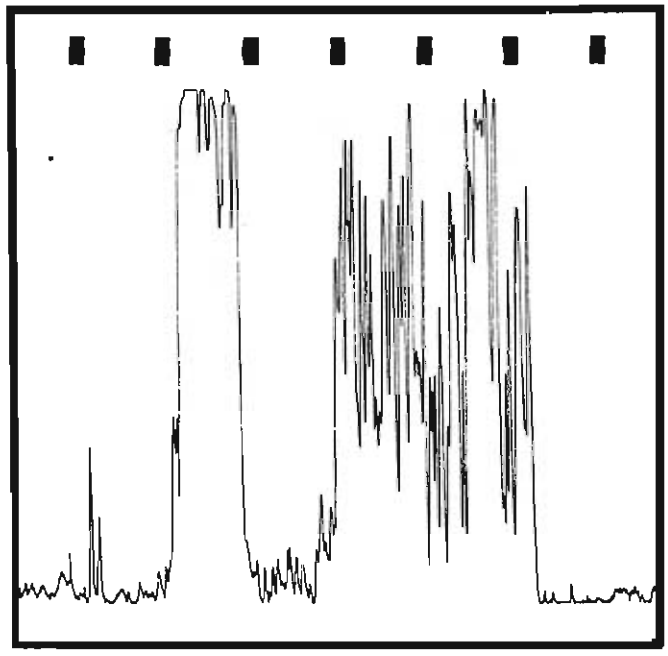


Fig. 3: A typical burst of radio noise recorded by the author on 14 September 1974, during the extensive solar storm which lasted from the 6th to the 19th

DXTV

Because the normal range of signals is extended during a sporadic-E disturbance, televiewers in the UK who still use Band I, 41-67 MHz, for BBC1, will receive a wide variety of continental radiotelephone, RTTY and beacon signals on top of their pictures. While those unfortunate viewers suffer, the TV DXers among us look at Band I for pictures from stations in Europe, Iceland, the Mediterranean area, Russia, and parts of South Africa (Fig. 4).

While a severe disturbance is in progress, it is interesting to watch a variety of television pictures from several countries, using similar frequencies, fighting for predominance on the screen as the sporadic-E clouds vary their reflecting angles. For example, a widespread disturbance will cause pictures from countries as far apart as the Federal German Republic and Iceland, and

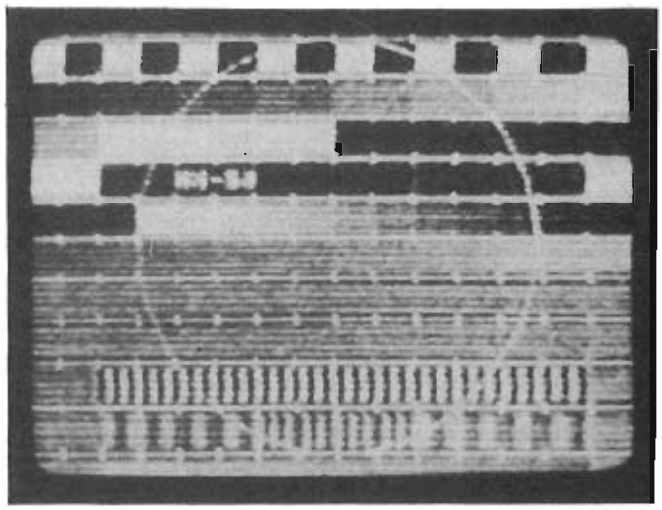
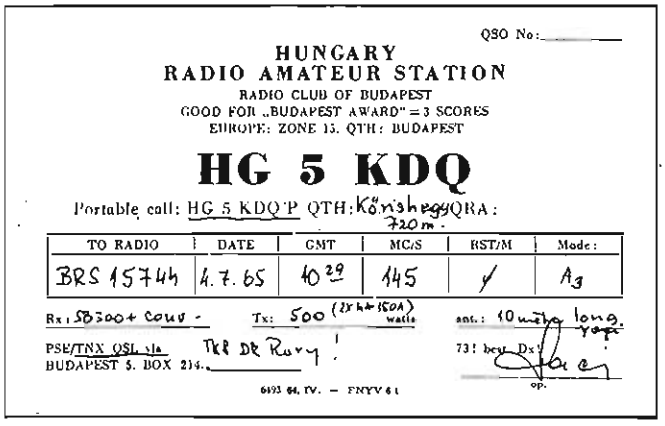


Fig. 4: A Russian test card received by the author during the 1979 sporadic-E season

Hungary and the USSR, on channels E2, 48.25 MHz and R1, 49.75 MHz, respectively, to mix together. This is a good reason why the serious DXer should have a copy of the *World Radio TV Handbook* to see the full list of stations that use the bands, allocated internationally, for both radio and television. Two books especially useful for the TX DXer are *Long Distance Television (TV-DX) for the Enthusiast,* by Roger Bunney, (Bernard Babani (Publishing) Ltd.) and *Guide to Work-Wide Television Test Cards* by Keith Hamer and Gary Smith (HS Publications, 7 Epping Close, Derby, DE3 4HR).

About three times during the season a big event comes up, and while this is in progress it is not unusual to hear dozens of continental radiotelephone signals between 30 and 45 MHz, many DXTV stations between 48 and 70 MHz and around 50 f.m. broadcast signals between 65 and 73 MHz; in fact at times, the entire range is chaotic. However, let this chaos be a warning, because the prevailing sporadic-E may suddenly extend its influence up to 150 MHz and signals from amateurs in Hungary, Italy and Yugoslavia may well be heard and worked from the UK in the 2m band, Fig. 5.


QSO No:

HUNGARY
RADIO AMATEUR STATION
RADIO CLUB OF BUDAPEST
GOOD FOR „BUDAPEST AWARD" = 3 SCORES
EUROPE: ZONE 15. QTH: BUDAPEST

HG 5 KDQ

Portable call: HG 5 KDQ/P QTH: Kőrishegy QRA: 720m.

TO RADIO	DATE	GMT	MC/S	RST/M	Mode:
BRS 15744	4.7.65	1029	145	/	A3

Rx: SB300+ conv. - Tx: 500 (12 kV 150A) watts ant.: 10 ele. long yagi

PSE/TNX QSL via BUDAPEST 5. BOX 214. TKS DE Rary!

73! hpe Dx! Jaci op.

6693 64. IV. – FNYV 61

Fig. 5: A QSL card from Hungarian amateur station HG5KDQ, heard by the author on 2m during an extensive sporadic-E on 4 July 1965

The F2 Layer

Basically, radio signals transmitted in the 20, 15 and 10m bands travel around the world, by skipping between the densely ionised F2 layer and the Earth's surface and, because the Earth rotates once in every 23hrs 56m, approximately half of the planet is in sunlight for about 12 hours, while the rest is in darkness. This means that only about half of the ionosphere is directly under the solar rays which determine its structure. Briefly, as the sun rises so the density of the F2 ionisation increases, reaching a peak around noon and then decreasing toward sunset. A useful reference book is *Amateur Radio Antennas,* Foulsham Sams. Although, broadly speaking, the "quiet" sun is responsible for the existence of the ionosphere sudden events, such as flares, associated with sunspots, can disrupt it for many hours.

Ever since the early 1930s, radio enthusiasts have found the high h.f. bands so full of interest that in recent years, the Radio Society of Great Britain has organised a world-wide beacon chain, operating in the 10m band, to assist with the study of radio wave propagation. Radio beacons are operational 24 hours per day and transmit a continuous tone which is periodically interrupted with its call-sign for identification purposes. The current International Beacon Project stations are situated in Australia VK2WI, 28·217MHz (awaiting confirmation), Bahrain A9XC, 28·245MHz, Bermuda VP9BA, 29·235MHz, Canada VE3TEN, 28·225MHz, Cyprus 5B4CY, 28·220MHz, England GB3SX, 28·215MHz, Germany DL0IGI, 28·205MHz, Mauritius 3B8MS, 28·210 MHz and New Zealand ZL2MHF, 28·230MHz.

Obviously, the strength and tone of a beacon signal will indicate the quality of the signal-path and the prevailing ionospheric conditions in that direction. Special log sheets for monthly reports are available from RSGB, 35 Doughty Street, London, WC1N 2AE. Another useful aid to DX in the home station is a world time clock, having a black and white scale to indicate which part of the world is in daylight or darkness. It is not uncommon to hear the BBC World Service warn their listeners about a prevailing ionospheric disturbance and, which is most helpful, they usually say which of their signal paths is being affected.

Aurora Borealis (Australis': southern hemisphere)

Briefly, an aurora is a complex natural phenomenon caused by particles from a solar event (Fig. 6) entering the Earth's atmosphere and temporarily ionising the gases approximately 100-200 miles above the Earth's polar regions. An aurora is a beautiful sight, but it can only be seen if it manifests when the skies are clear and during the hours of darkness. However, an aurora can be identified at any time because of the strange effect it has upon radio signals, mainly in the v.h.f. region.

For example, the letter "Q" sent in Morse code would, under normal conditions, sound like "dah, dah, dit, dah" but when the signal is reflected from an auroral display, it sounds raspy, like, "ror, ror, ri, ror". In the first instance, the signal has a clean T9 note and is received directly from the transmitter over a limited v.h.f. range, but when the same signal, usually transmitted in the 2m band, bounces off an aurora, it is reported simply as Tone-A and can travel for more than 1000 miles. An aurora reflected s.s.b. signal sounds like a ghostly whisper and very careful tuning is required to resolve it.

When aurora is present, the v.h.f. operator must direct his beam aerial towards the north, swinging it slightly for peak signal strength, because wherever the transmitter is

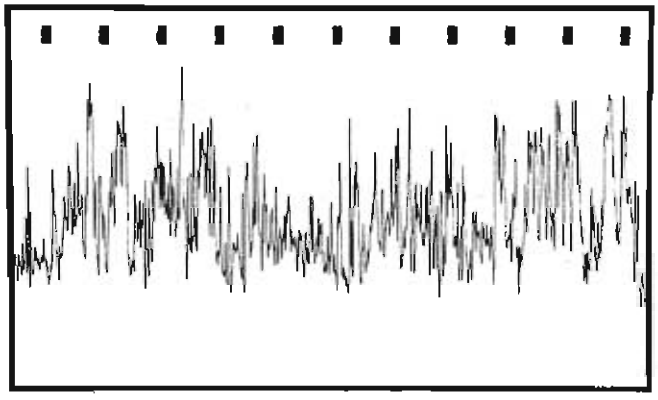


Fig. 6: An 11-minute sample of severe radio noise received by the author during the September 1974 solar storm. An extensive aurora manifested during the afternoon and evening of the 15th

located, its signal will be received via the prevailing aurora. Special log sheets for these events are available to members from RSGB Headquarters and reports giving time, call-sign of station heard or worked, signal strength and your aerial compass bearings are vital to the work of the Society's auroral co-ordinator.

Meteor Trail Reflection

Every hour of the day, tiny solid particles from inter-planetary space, known as meteors, burn up within the Earth's atmosphere, leaving behind them decaying trails of ionised gas from which v.h.f. radio signals are reflected. Although the duration of a trail depends upon the size of the particle, the majority seem to last for only a few seconds.

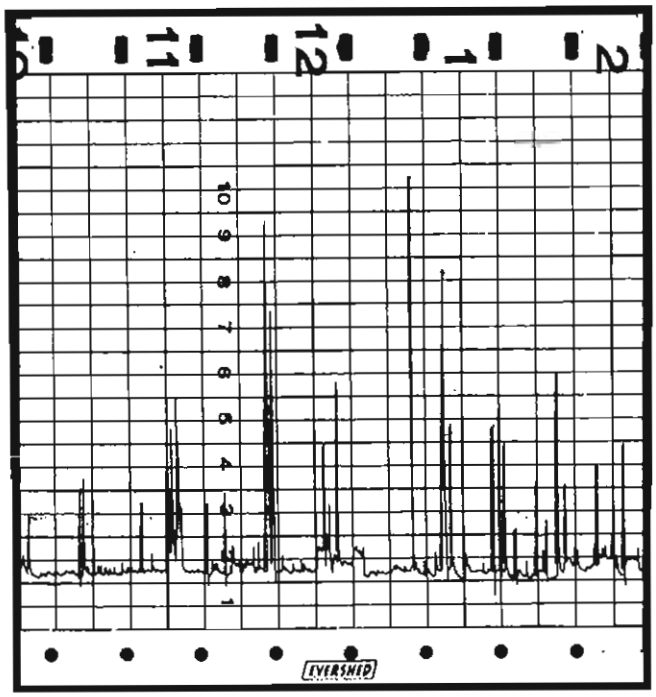


Fig. 7: An 8-minute section of recording chart used by the author, showing about 25 meteor "spikes". Each spike is a burst of signal from the broadcast station at Gdansk, 70.31MHz, bouncing off a meteor trail

A careful study of the heavens on a clear dark night will reveal these particles, colliding with the atmosphere, as streaks of bright light shooting across the sky (often called shooting stars), and rapidly fading away. Periodically, on its orbit around the sun, the Earth encounters separate multitudes of particles, called meteor showers, and named after the constellation of stars from which direction the radiants of the meteors appear to come. The British Astronomical Association's handbook for 1980 lists the dates for the major showers as: Quadrantids, January 1 to 6, peak 4th; Lyrids, April 19 to 24, peak 21st; Perseids, July 25 to August 18, peak 12th; Leonids, November 15 to 19, peak 17th, and Geminids, December 7 to 15, peak 14th.

Many astronomical societies have meteor sections, and during the life of a shower, groups of members study a given area of the sky, estimate the number of meteors seen, and describe the duration and colour of their trails. Unfortunately, moonlight and overcast skies are the natural hazards for the visual astronomer, so this is where radio, unaffected by these conditions, can be used for meteor study.

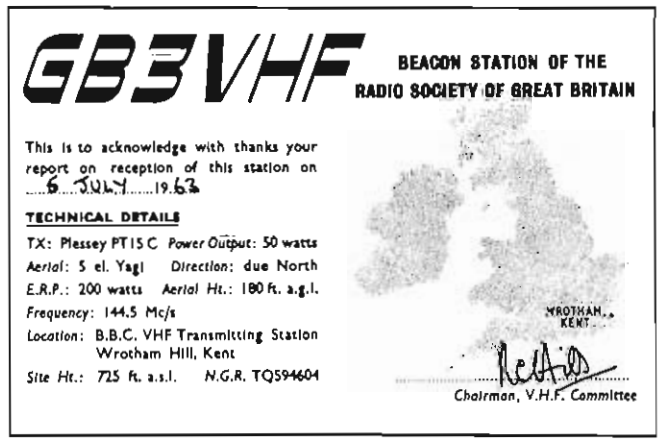
For about four years during the early 1970s, for approximately 15 hours each day, the author used a purpose-built radio receiver to count the number of times that the signal from the Polish broadcast station at Gdansk, 70.31MHz, was received in the UK via meteor trail reflection, Fig. 7. The results were fascinating, especially during a meteor shower when the daily count would rise toward the peak and then decline as the Earth passed through the shower. During the peak of a shower many broadcast listeners and TV DXers try to identify bits of signal bouncing off the trails, and radio amateurs, using the 2m band, repeat their own call-signs in high speed c.w. for several minutes and then listen on the frequency, for the same amount of time, hoping to piece together tiny parts of a reply. Although using meteor scatter for amateur communications is a chancy business because both ends of the QSO, often more than 1000 miles apart, may have to repeat their respective information many times before a two-day contact is confirmed, a fantastic amount of DX has been worked during the past twenty years.

The Troposphere

The first 5-10 miles above the Earth's surface is known as the Troposphere, and radio and television signals above 100MHz are greatly influenced by this region of the atmosphere. Under normal conditions, the range of a signal transmitted between 100 and 300MHz is approximately 100 miles but this gradually gets less as the radio frequency rises.

During a tropospheric opening, which usually follows a spell of good weather and high atmospheric pressure, v.h.f. and u.h.f. signals often travel for more than 1000 miles and cause interference to radio or television receivers, tuned to their local stations sharing the same frequency. Radio amateurs often check Band III, (176-215MHz) and Bands IV and V (471-854MHz) television for similar interference if they suspect an opening. If the interference is present, they can look for DX on the 2m (144-146MHz) and 70cm (432-440MHz) bands.

The f.m. broadcast band, 88-108MHz, is a borderline case because it can be affected by an intense sporadic-E or a minor tropospheric disturbance. Most European countries use this range for their national and local broadcasting and, when an opening occurs, it is not uncommon to hear continental signals overpowering the BBC stations. During one big event the author counted 40 "extra" stations in the band, with only a horizontal dipole


GB3VHF

BEACON STATION OF THE RADIO SOCIETY OF GREAT BRITAIN

This is to acknowledge with thanks your report on reception of this station on 6 JULY 1963

TECHNICAL DETAILS

TX: Plessey PT15C Power Output: 50 watts
Aerial: 5 el. Yagi Direction: due North
E.R.P.: 200 watts Aerial Ht.: 180 ft. a.g.l.
Frequency: 144.5 Mc/s
Location: B.B.C. VHF Transmitting Station Wrotham Hill, Kent
Site Ht.: 725 ft. a.s.l. N.G.R. TQ594604

WROTHAM, KENT

Chairman, V.H.F. Committee

Fig. 8: An historic QSL card from the RSGB, acknowledging a signal report for their first permanent v.h.f. beacon, then on 144.5MHz

feeding the receiver. No doubt with careful tuning and a big beam aerial many more would have been located.

The 2m band is full of surprises throughout a tropospheric opening, using all modes, over a wide area from Scandinavia to the Mediterranean Sea and all parts of the UK. The first signs of an opening can come from any one of the chain of 2m beacons, established by the RSGB, ranging from Cornwall GB3CTC, 144·915MHz, to Angus GB3ANG, 144·975MHz and Northern Ireland GB3GI, 144·945MHz, to Wrotham, Kent GB3VHF, 144·925MHz (Fig. 8). Having decided, from the number of UK beacons heard, the extent of the prevailing lift, it is worth looking for signals from the continental beacons such as DL0PR, 144·910MHz, FX3THF, 144·905MHz, ON4VHF, 145·990MHz, OZ7IGY, 144·930MHz, SK4MPI, 144·960MHz to name a few.

Another good propagation indicator is the 2m repeater network which now provides considerable coverage of the UK. Periodically, each repeater identifies itself by transmitting its official call-sign, in c.w., on its allotted output channel, R0 to R7, which range from 145·600 to 145·775MHz in 25kHz steps. Propagation beacons can also be heard in the 70cm band from Emley Moor GB3M, 432·91MHz and Sutton Coldfield GB2SUT, 432·89MHz. The 70cm repeater output channels, RB0 to RB14, UK only, can also be heard in 25kHz steps, between 433·000 and 433·350MHz inclusive. Outside the UK, the repeater output channels range from 434·600 to 434·950MHz.

Atmospheric Pressure

Another valuable tool in the shack is a barometer, or, better still, a barograph, which is a superior barometer with a pen arm mechanically coupled to its bellows, so that the changes in atmospheric pressure can be recorded on a calibrated paper chart. Changes in the prevailing weather conditions can affect radio signals in the 2m and 70cm amateur bands and television signals in Bands III, IV and V. Sometimes an opening will build up over several days but, more often, a spell of bad weather and low pressure will suddenly end and a ridge of high pressure will move in (Fig. 9). The barometer will then rise sharply and, once it is above 30·0in, the v.h.f.s are vulnerable and the time is right to listen for the propagation beacons. After more than 15 years of observation, the author has found that when the pressure is above 30.0in and then rises further, an extensive tropospheric opening is likely to occur around the time when the pressure starts to fall.

Contests

Every year, the RSGB, in conjunction with the International Amateur Radio Union, (IARU Region I), arranges a number of contests in all amateur bands for licensed amateurs and SWLs. These events are usually full

Continued on page 36

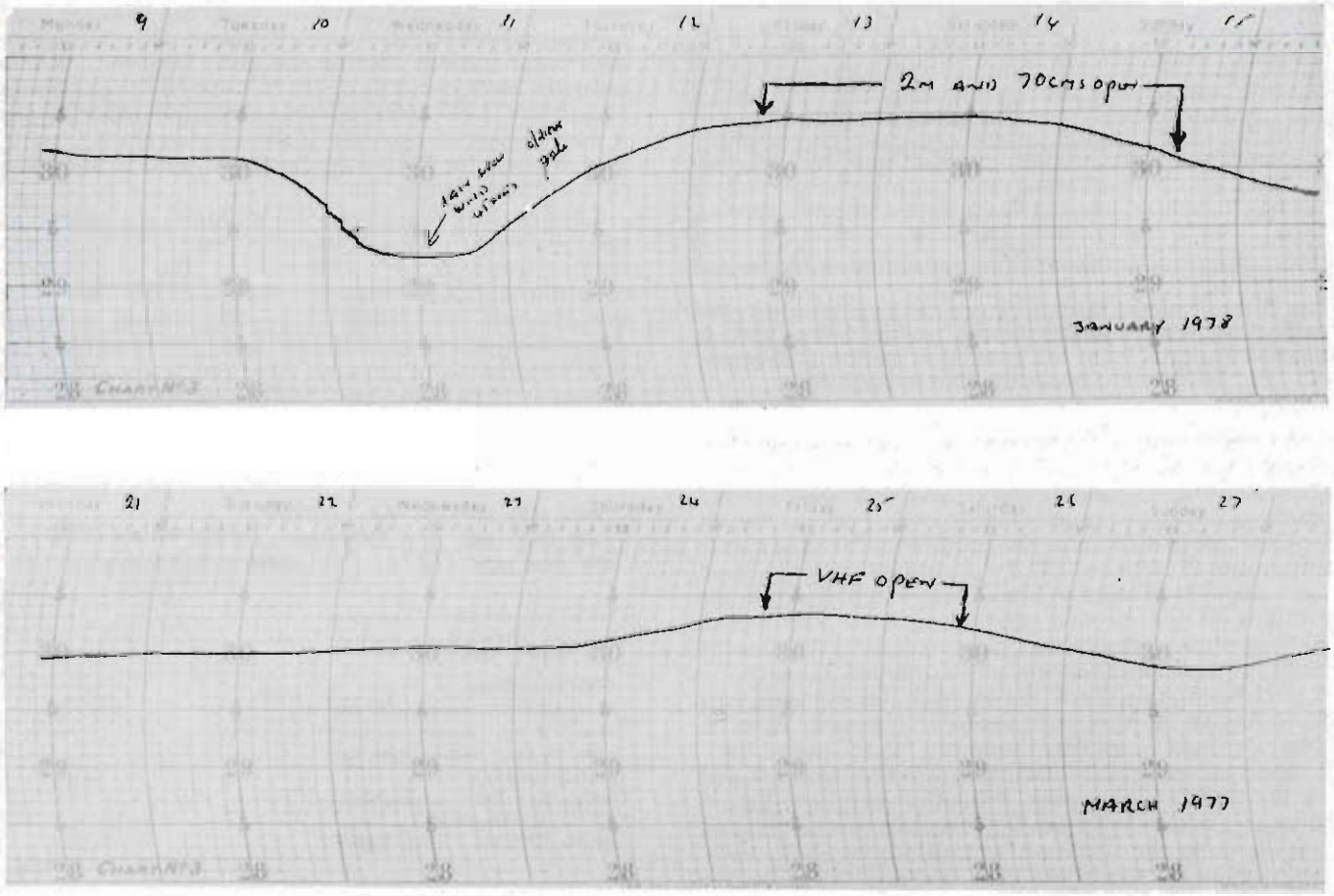


Fig. 9: Important changes in atmospheric pressure, recorded by the author's barograph at his home in southern England. The upper chart shows the timing of a 2m and 70m opening accompanying the high a.p. that followed a big storm. The lower chart shows a typical brief tropospheric opening, which distributed Band II and the 2m band

VSWR problems at VHF

Fred JUDD G2BCX

Voltage Standing Wave Ratio (v.s.w.r.) is a subject frequently discussed by radio amateurs but somehow it rarely seems to be fully understood. Is a low v.s.w.r. really important and if so what is the maximum ratio tolerable? Often that 1:1 reading, technically a perfect match, may be quite misleading, for reasons which we will consider later in the text.

Many factors determine the loss of radiated power between transmitter and aerial, including poor insulation, non-resonance, aerial too close to others or even the choice of metal from which the aerial is made. Two areas often overlooked are the feeder cable (where inferior construction will cause problems) and the possibility of a mismatch between transmitter and feeder, feeder and aerial, or a combination of all these parameters. All r.f. feeders, such as open lines, exhibit a degree of loss, coaxial cables usually producing the worst effects. This, together with varying degrees of v.s.w.r. often gives rise to ambiguity when determining the effect of the v.s.w.r. itself.

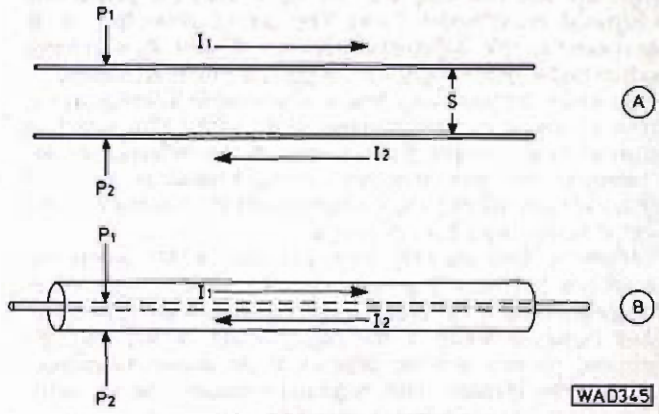


Fig. 1: Configuration of commonly used transmission lines. (A) open wire (B) coaxial. See text for explanation with regard to currents I_1 I_2

Matching

Virtually any cable that carries power from "A" to "B" could be regarded as a transmission line: a pair of wires for instance, from a battery to a lamp. Considering this example further, it will be appreciated that as the length of the "transmission line" increases so does its resistance, and in consequence the lamp grows progressively dimmer.

A similar principle can be applied to the cable connecting a transmitter to an aerial but in this case the source of energy would be high frequency, and not d.c. Therefore the inductive and capacitive properties of the feeder combine to produce an impedance to the transfer of power. This is referred to as the characteristic impedance of the cable, and it remains almost constant, virtually irrespective of frequency.

Purely resistive losses cannot be completely disregarded of course but steps can be taken to prevent radiation loss. If the characteristic impedance of the line equals both the source and load impedance then two conductors can be employed, close enough together for their respective electro-magnetic fields to cancel out.

Transmission lines favoured by amateurs are open line, which consists of two parallel conductors spaced a small fraction of a wavelength apart, and coaxial cable, in which one conductor is effectively shielded by the other whilst electrically behaving as an open two-wire line. The concept is shown in Fig. 1 in which the currents I_1 and I_2 are flowing. If the current I_1 at any point (P_1) along the line has the same amplitude as current I_2 at the opposite point (P_2) the fields thus produced will be equal in amplitude but, as they are moving in different directions, out of phase. This will not necessarily be 180°, so in some instances there may be a small amount of radiation, although for practical purposes it can be disregarded. Certain conditions can exist which will cause an appreciable difference in the phasing

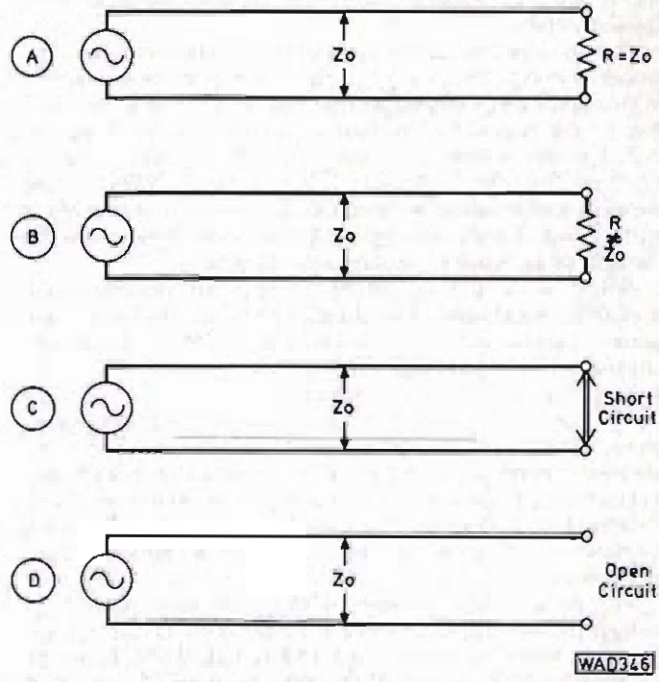


Fig. 2: (A) Line matched to load, R = Z_0. (B) Line partially matched, R greater or smaller than Z_0. (C) and (D) Line with short or open-circuit. See text

of the two line currents however, and in such circumstances far more radiation can take place.

Consider Fig. 2(a). Here we have connected one end of a transmission line to a generator of equal impedance, the

other being terminated in the purely resistive load R, which has the same ohmic value as the line impedance Z_0. Under these conditions any current travelling down the line will flow into the resistance, which presents itself as an extension of the line. Since a pure resistance has no inductive or capacitive reactance, the line will be perfectly matched and none of the power (I^2Z_0) will be returned to the generator. An infinitely long transmission line would exhibit the same characteristics provided its impedance remained constant, although the power would ultimately be absorbed in overcoming the resistance of the line itself, of course.

Now turn to Fig. 2(b). The resistance of load R does not equal the line impedance in value, and so the power not dissipated is reflected back. The power absorbed by R decreases as the difference between R and Z_0 increases and so under these conditions a greater mis-match exists.

To make the position clearer, the term *incident power* is given to the power transferred to R, whilst that which is returned to the source is referred to as the *reflected power*. Therefore we can produce a mathematical ratio of reflected to incident power which gives an indication of the degree of mis-match in the circuit.

When R becomes zero, as in Fig. 2(c), all the power will be reflected. This will also be the case if R is regarded as an open circuit (Fig. 2(d)). Power will flow in both directions however when a mis-match does occur, and the reflected portion will be dependent on phase differences between the incident and reflected voltages and currents. These interact to produce a *standing wave.*

Standing Waves

The diagrams of Fig. 3 serve to illustrate how standing waves are formed when varying degrees of mis-match are encountered.

In Fig. 3(a) there is an open circuit at the end of the line which prevents the flow of current. The current waveform at this point has zero amplitude and in effect cancels itself, due to the reversal of polarity. Current travels along the line, but the voltage is across it of course, and so is not reversed by this reflection. The electric fields of the forward and reflected waves add up to twice the amplitude and if line losses are ignored the total power can be thought of as being returned to the generator.

When R is a short circuit, Fig. 3(b) illustrates the prevailing conditions. The amplitude of the standing wave pattern can be seen to be the same as for open circuit conditions, except that it has moved along to meet the zero voltage state at the end of the line.

In Figs. 3(c) and 3(d) we can see the conditions produced when R is greater or smaller than Z_0 by a given amount, creating a standing wave of lesser amplitude due to the fact that only part of the forward power is reflected. Finally, Fig. 3(e) shows the situation where $R = Z_0$. Here no power is reflected and the line carries a uniform travelling wave.

The ratio of the maximum (V_{max}) to minimum (V_{min}) voltage of the standing wave is referred to as the *voltage standing wave ratio* (v.s.w.r.) and is calculated from the expression $R:Z_0$ when R is greater than Z_0 or $Z_0:R$ when R is the lesser quantity.

The perfect match, rarely achieved in practice, would have a v.s.w.r. of 1:1. When a mis-match exists, this ratio becomes much larger until, with an obsolute open or short circuit it becomes infinite. Such a situation should be avoided, especially in the case of transistorised apparatus, where high levels of reflected power will almost certainly result in damage unless some form of protection is provided.

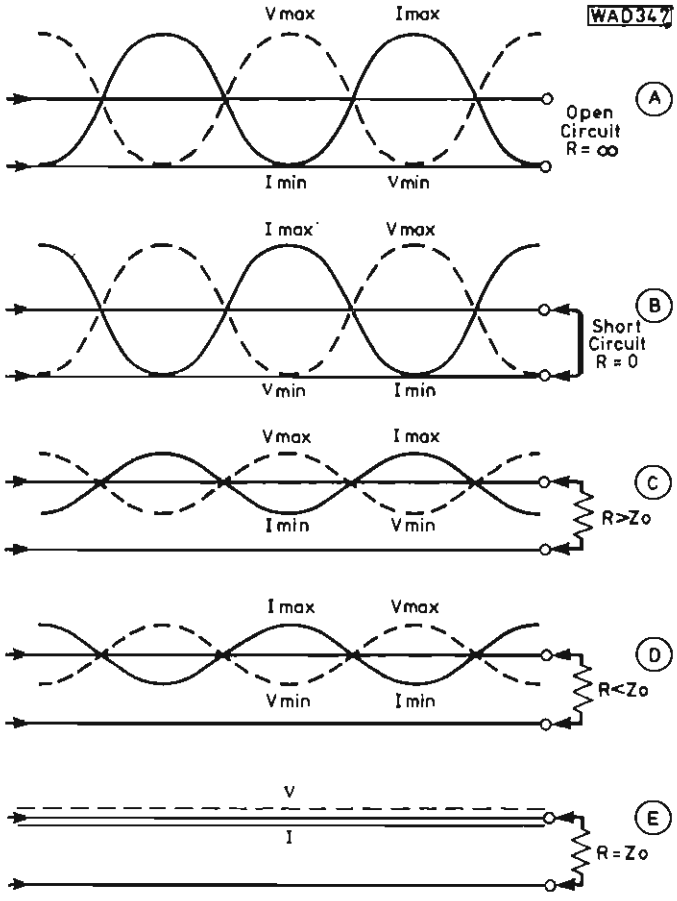


Fig. 3: (A, B, C, D) Voltage and current distribution of standing wave due to mismatch. (E) Line matched: V and I become a travelling wave

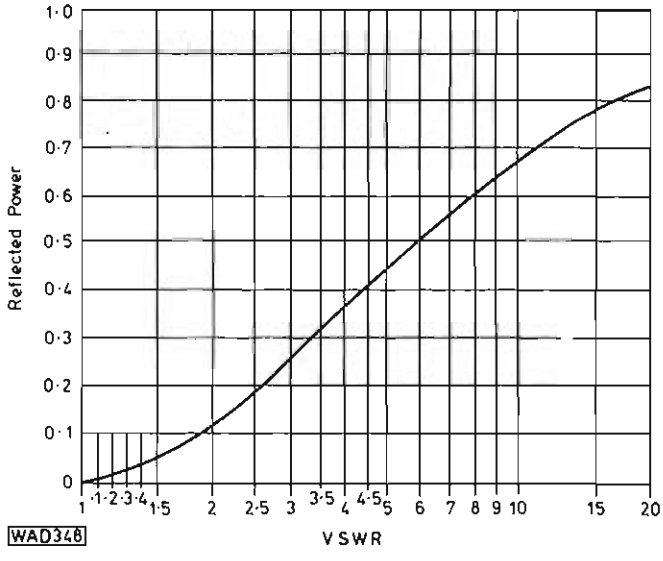


Fig. 4: Reflected power plotted against v.s.w.r. (see text)

The Effects of VSWR

Possibly the loss of power to an aerial due to standing waves on the transmission line may not be as serious as many are led to believe. Provided the line is of low-loss construction the attenuation due to a v.s.w.r. of, say, 2:1 may only be around 0·5dB.

The graph in Fig. 4 shows the percentage of returned power (lost to the aerial) for varying values of v.s.w.r. Some slight discrepancy may occur which must be attributed to the natural losses of the transmission line, and this will affect both forward and reflected power readings. For example, the dotted line in Fig. 5 shows that for a measured v.s.w.r. of 2:1 and a line loss of 3dB along the total length, the true v.s.w.r. is about 5:1, representing a considerable additional loss due to reflected power. This clearly demonstrates the need to use low-loss transmission line.

One should really aim for a v.s.w.r. of less than 1·5:1, especially if the total cable loss is likely to be greater than about 2dB. With around 30m of cable having an attenuation of 2·5dB the additional losses due to a measured v.s.w.r. of 1·5:1 will be less than 1·0dB.

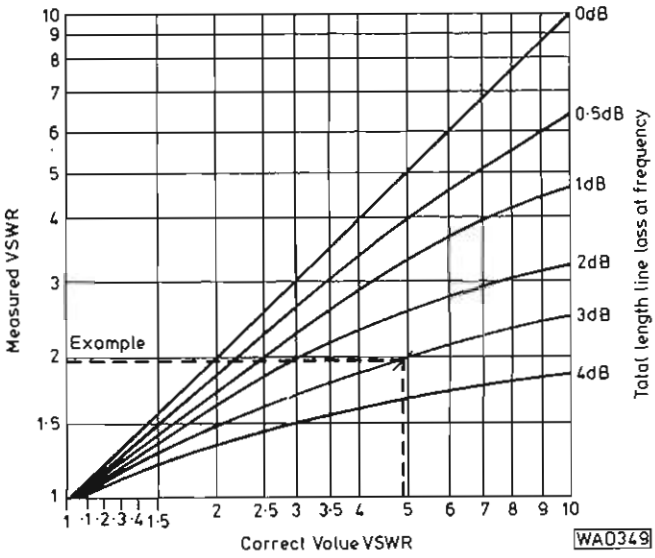


Fig. 5: True v.s.w.r. is dependent on transmission line loss (see text)

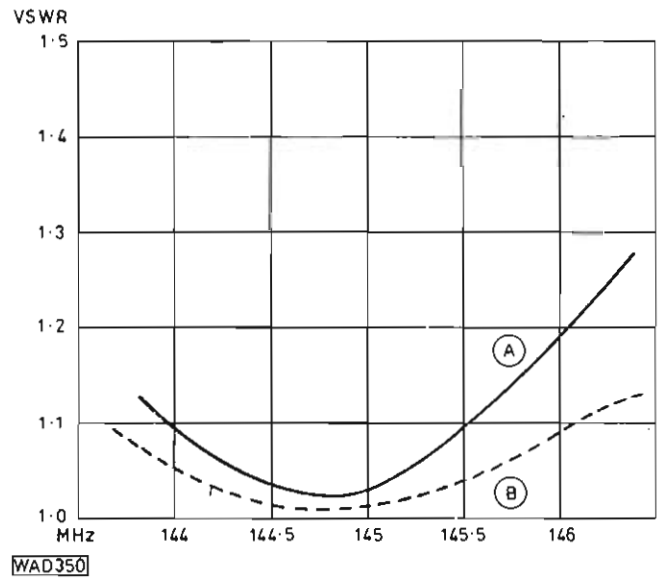


Fig. 6: Typical v.s.w.r. (A) From a well matched line and aerial. (B) Curve flattened due to line loss

When line losses are high, the additional loss caused by standing waves tends to be constant: the amount of power reflected from the aerial is reduced in proportion to the overall attenuation in the feeder. As an example, if the line loss is 6dB only 25 per cent of the applied power will actually reach the aerial. Should the v.s.w.r. at the aerial be 4:1, due to a mis-match, then 36 per cent of the power applied to it would in fact be reflected. However, we have already established that only 25 per cent of the original power has reached the aerial, so the true reflected power is:

$$0{\cdot}25 \times 0{\cdot}36 = 0{\cdot}09\ (9\%)$$

The transmission line characteristics further reduce this by 6dB, so we have

$$0{\cdot}09 \times 0{\cdot}25 = 0{\cdot}02\ (2\%)$$

This represents the actual power arriving back at the transmitter, and would result in a low v.s.w.r. reading at the transmitter end of the feeder—in this case, something like 1·3:1.

On the other hand, with a very low-loss line, a high v.s.w.r. may cause a higher power loss, although the total may be relatively small by comparison with that actually reaching the aerial. A v.s.w.r. of 10:1 (True) on a line having a loss of only 0·3dB would result in an additional loss of about 2dB.

Low v.s.w.r. readings do not necessarily indicate a "Go" situation, and should be closely examined if transmission line losses have not been taken into account. For example, with a 15m length of UR43 coaxial cable having a true v.s.w.r. of 2:1, the reading obtained could be as low as 1·1:1. With old or otherwise inferior coaxial cable exhibiting high loss, virtually no reading at all could occur. On the surface of it, this would suggest a v.s.w.r. of 1:1.

A typical v.s.w.r. readout for a well-matched aerial covering the 145MHz band is given in Fig. 6. With above-average line losses, the response could easily be represented by the dotted curve.

The relationship between transmission line loss and v.s.w.r. can be demonstrated in an alternative way, based on a method of assessing losses in coaxial cable by measuring the v.s.w.r. when the cable is terminated in a short-circuit. *This technique should never be employed when transistorised r.f. power amplifiers are used, incidentally.*

From Example A in Fig. 7 it can be seen that a v.s.w.r. of 1·5:1 would indicate a cable loss of 6·7dB for the total length. This is because the forward power is attenuated in the first instance, and consequently there is a reduction in the quantity of power reflected, which itself is attenuated and results in a low v.s.w.r. reading.

Example B on the same drawing shows that the cable loss is much lower, and the high v.s.w.r. of 4:1 indicates that most of the power travelling along the cable is also reflected. The attenuation of the cable is only a little over 2dB, so this serves to qualify our preceding conclusions.

Ideally, power and v.s.w.r. measurements should be made both at the transmitter and at the aerial, otherwise erroneous readings could be obtained due to other considerations, such as the length of the line in relation to the frequency being used. If the reflected voltage happens to be at or near a minimum at the transmitter end, then low v.s.w.r. figures could be obtained. By the same rule, it is often possible to reduce an otherwise high v.s.w.r. by pruning a short length off the transmission line—or, indeed, by adding to it. This will not effect a cure as such however: it does not remove a standing wave that results from a mismatch.

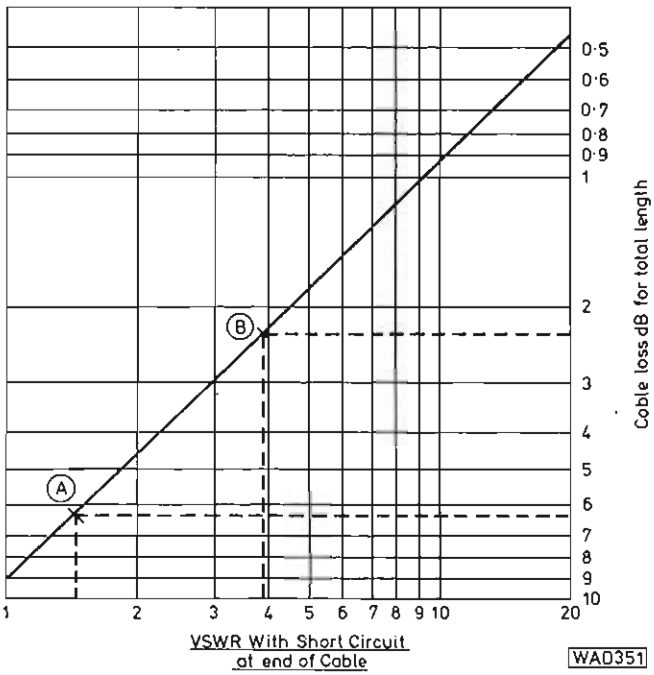


Fig. 7: Attenuation loss in dB for a given length of cable by reading v.s.w.r. into short-circuit termination. See text regarding application of this test

Use of VSWR and Power Meters

Really accurate v.s.w.r. and power meters suitable for v.h.f. applications tend to be on the expensive side, although the model marketed by *Telecommunications Associates* may be considered reasonable. The type of power meter fitted to amateur transmitters and transceivers can rarely be relied on for accuracy. In fact, occasionally some instruments can actually introduce a problem due to poor matching with the feed cable. So also can external r.f. power amplifiers, which incidentally should never be in circuit when first testing an aerial for a match.

Obviously low grade meters should be checked against a known standard and with a dummy load known to provide an accurate match with the transmitter output. In this way a v.s.w.r. approaching 1:1 should be obtained and full output power indicated if the meter is provided with this facility.

Testing a New Aerial

Initially a new aerial should be tested with only a short feeder, to establish that a good v.s.w.r. is possible. A preliminary check with a receiver is also worthwhile, if only to ensure that the aerial is giving some sort of results before applying r.f. power.

Start the tests with fairly low power levels, if possible. This will prevent damage to the transmitter p.a. stage if a serious problem should arise.

When the aerial is proved, the full length of feeder should be fitted and maximum power applied.

One of the most simple and effective methods of checking for the presence of r.f. alongside an aerial is a small fluorescent tube, of the type often used in caravans. These are usually rated at about 6 watts, and when touched against a *voltage* point on an aerial to which a 10 watt transmitter is attached, should light almost to full brilliance. ●

'2BCX BEAM

continued from page 25

sealed everywhere against the ingress of water, e.g., around the entry of the driven elements and matching line, etc. Suitable sealants are Scotchkote, Araldite or Evostik. Give the phasing line and its bridge spacers one or two coats of polyurethane varnish. This is important for the prevention of r.f. leakage that could occur with rain or frost.

Finally, the radiation pattern of the aerial which is shown in Fig. 7 was obtained under ideal conditions and is the true pattern with a main lobe beam width of 30° at 3dB down. The radiation pattern in the vertical mode is almost identical except that the main lobe is a degree or so wider at 3dB down. The second pattern, Fig. 8, was taken from signals arriving from a fairly long distance and with the aerial operating in a normal environment, i.e., at the top of its mast at the writer's home QTH. As will be seen, there is no distortion of the main lobe, and the minimal differences in the small side and rear lobes are due to random reflection likely to occur in normal conditions. Finally, it may be worth mentioning that the overall performance of this aerial in terms of gain and radiation pattern is virtually identical with that of a well-known commercial 16-element beam with a total length of 6m. ●

References

1. *Antennas*. Kraus. McGraw-Hill
2. *Antenna Arrays with closely spaced elements*. Proc. IRE. Feb. 1940

PATH OF THE WAVES

Continued from page 32

of interest because they are well supported by both individual and group entries and, should a contest coincide with an atmospheric disturbance, then there is plenty of super DX about and the scores mount up.

Conclusion

One of the most comprehensive and well-illustrated works on this subject, and a must for the scientifically minded reader's book-shelf, is the chapter on propagation in the 5th edition of the RSGB's *Radio Communication Handbook, Vol. 2*. There, the authors rightly say: "The field of radio propagation is one in which radio amateurs can still usefully contribute something to complement the work of the professionals".

As there are no simple answers or hard and fast rules about the propagation of radio waves, or the behaviour of the sun or the Earth's atmosphere, we can only try to unravel the mysteries by consistent observations; we make a contribution to science by reporting our findings to the RSGB or the appropriate section of a technical journal. ●

'SLIM JIM'
2-METRE AERIAL

F.C. JUDD FISTC, MIOA, Assoc.IPRE, A.Inst.E (G2BCX)

This is a vertically polarised omnidirectional free space aerial for two metres but which will operate in the same way for higher or lower frequency bands by scaling the dimensions accordingly. It has a radiation efficiency 50% better than a conventional ground plane due to its low angle radiation, is unobtrusive, has no ground plane radials, and therefore has low wind resistance. The name "Slim Jim" stems from its slender construction (it is only 60 inches long for 2 metre operation) and the use of a J type Integrated Matching stub (JIM) that facilitates feeding the aerial at the base, thus overcoming any problem of interaction between feeder and aerial. The feed impedance is 50 ohms.

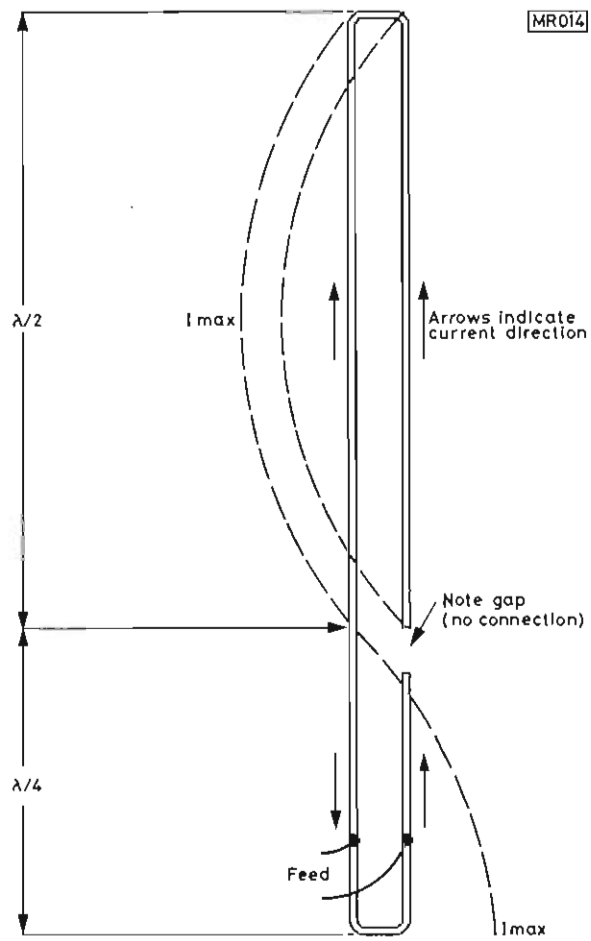


Fig. 1: The basic aerial, showing direction of current flow and phase reversal in matching stub.

How the 2BCX "Slim Jim" operates

Basically it is an end-fed, vertically operated, folded dipole (**Fig. 1**). As with all folded dipoles, the currents in each leg are in phase whereas in the matching section they are in phase opposition, so little or no radiation occurs from the matching stubs. Correctly matched the VSWR will be less than 1·5 to 1 and will remain so across the band. It can be constructed for use as a fixed home station "omni" or for portable operation, and the aerial has been used for mobile operation mounted on a short stub mast attached to a rear bumper; at sea a special version is used, completely enclosed in a plastic tube for protection against salt water.

Construction

The "Slim Jim" may be constructed from $^1/_4$ or $^3/_8$ inch diameter aluminium tube, stiff coathanger (galvanised iron) wire or 300 ohm ribbon feed. The spacing between the parallel elements is not critical

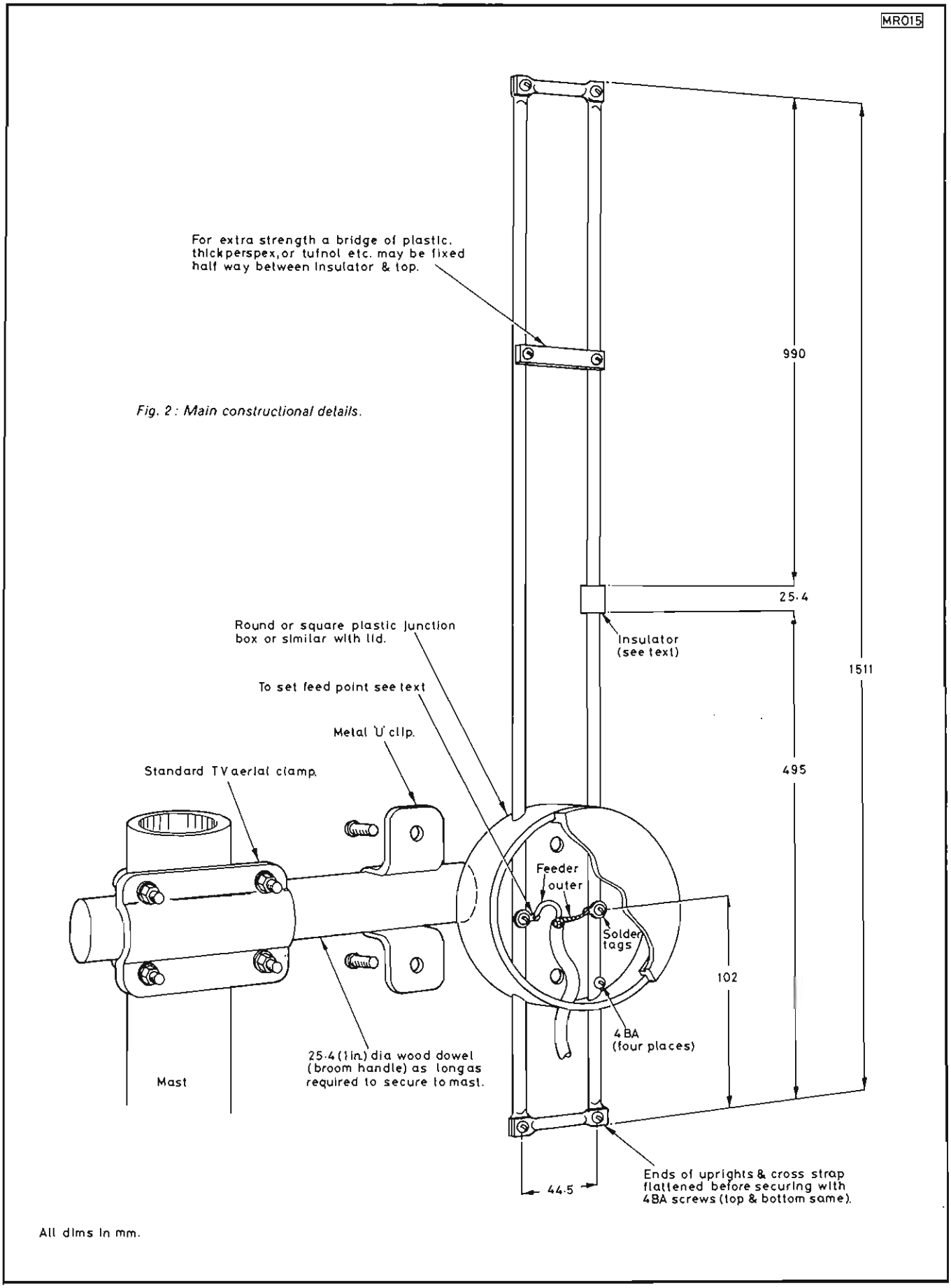
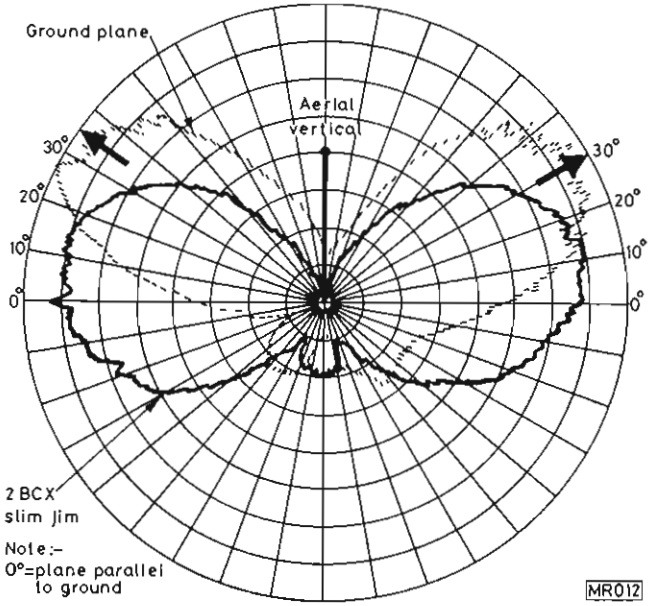

MR015
For extra strength a bridge of plastic, thick perspex, or tufnol etc. may be fixed half way between insulator & top.
990
25·4
Insulator (see text)
1511
Round or square plastic junction box or similar with lid.
To set feed point see text
Metal 'U' clip.
Standard TV aerial clamp.
495
Feeder outer
Solder tags
102
4BA (four places)
25·4 (1 in.) dia wood dowel (broom handle) as long as required to secure to mast.
Mast
44·5
Ends of uprights & cross strap flattened before securing with 4BA screws (top & bottom same).
All dims in mm.

Fig. 2 : Main constructional details.

and neither is the overall length, providing this is within $\pm \frac{1}{4}$ inch.

Details for a strongly made version for fixed station use outdoors are given in **Fig. 2,** in which the diagrams are self-explanatory and dimensions are included. The only comment called for is on the insulation between the return half of the folded radiator and the top of one side of the matching stub. This may be a piece of thick perspex, tufnol or p.t.f.e. drilled to take the rods (they must not touch), which can be set in with Araldite.



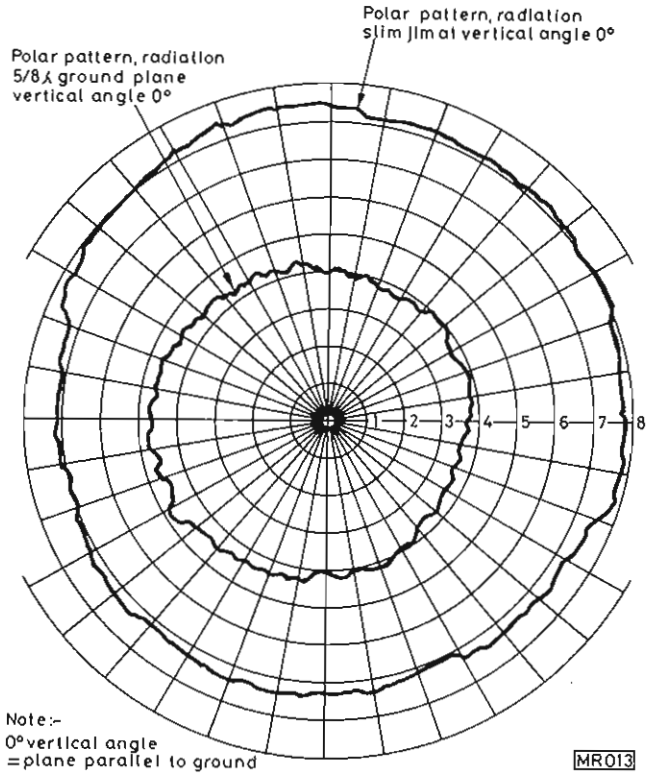


Fig. 3, above, where the 5/8 wavelength ground plane radiation angle is 30° or more (dotted line), and the "Slim Jim's" at virtually 0°. Fig. 4, top right, providing omnidirectional patterns of a 5/8 gr.p. at 0° vertical angle. Both patterns from models at 650MHz.

Response

The polar diagrams shown in **Figs. 3 and 4** explain the "Slim Jim's" improved efficiency over the 5/8 wavelength ground plane, in spite of its claimed 3dB gain over a dipole or similar ground plane. Fig. 3 shows that the "Slim Jim" vertical angle of radiation is almost parallel to ground, so maximum radiation is therefore straight out (and all round) which is what we want. With all ground plane aerials, including those with radials of more than $\frac{1}{2}$ inch length, radiation is tilted to an average angle of 30° or more. The dotted line in Fig. 3 is that from a 5/8 wavelength Gr.P aerial with 6 quarter-wave radials.

Now examine Fig. 4. The outer line is the (omnidirectional) radiation from the "Slim Jim" at a vertical angle of 0° e.g., on a plane parallel to ground. The inner line shows the loss of radiation, by comparison, from a 5/8 wavelength ground plane at the same angle and that loss can be around 6dB! This has been verified with full size 2 metre aerials as well as with UHF scale models on the writer's aerial test range. Many 2 metre operators already using the "Slim Jim" in place of a ground plane will confirm its efficiency.

Setting Up

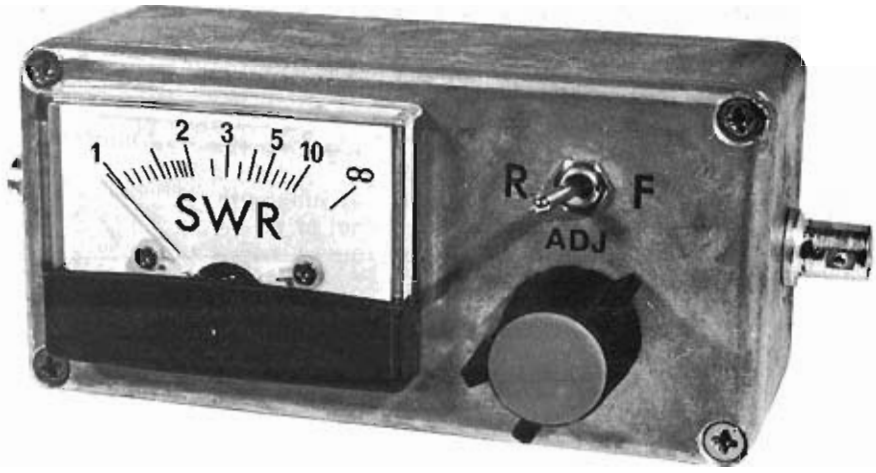
The feed point may be protected from rain as shown in Fig. 2, by a circular plastic junction box, with a screw-on lid, but the correct feed point must be found first. The best way of doing this is to complete the construction of the aerial and stand it upright in the room near the transmitter but clear of other conductors. Use the full length of feeder required to reach the aerial when finally in situ. Clip on at about 4 inches up from the bottom as in Fig. 2. Adjust slightly up or down for minimum S.W.R. and maximum power into the aerial. Note points of contact and then fit solder tags as shown ready for the feeder soldered connections. The plastic box may now be fitted and the completed aerial and feed protector box can be given a coat or two of polyurethane varnish before final installation. Fig. 2 shows methods of mounting on a mast with a TV aerial claw clamp such as those made by Antiference.

Positioning of the "Slim Jim"

Ideally the aerial should be as high as possible and clear of other aerials or conductors. It will, however, operate quite well indoors in the loft, or even in a living room, but obviously with a lower range.

If the "Slim Jim" is constructed from coathanger wire, galvanised iron wire or 300 ohm ribbon feeder, while other considerations remain the same, the space between the elements may be reduced to about 1 inch. The whole of the aerial, made like this, could be housed in plastic water pipe. Being compact, the "Slim Jim" can be carried around quite easily for portable operation on holidays, etc. Please note the name "2BCX Slim Jim" is copyright and the design is exclusively that of the writer. ●

A 2 metre VSWR Bridge



M. H. Tooley BA G8CKT & D. Whitfield BA G8FTB

Introduction

Matching the aerial to the transmitter, in order to obtain maximum radiated power, is an important consideration for any radio amateur hoping to obtain the best results from his equipment: this can be achieved by using some form of standing wave meter in the tuning-up procedure. The standing wave ratio (s.w.r.) is a measure of the efficiency of an aerial system: the closer the s.w.r. is to unity, the greater the proportion of transmitter power actually radiated. Although the s.w.r. only approaches unity under ideal conditions, in practical situations its measurement will provide a very useful evaluation of the system's performance.

The instrument described is an s.w.r. bridge which will provide a constant, on-the-air reading whilst allowing meaningful measurements to be made on the relative merits of different aerials and aerial sites. It is suitable for use in the feeders of v.h.f. transmitters having outputs of between 1W and 100W.

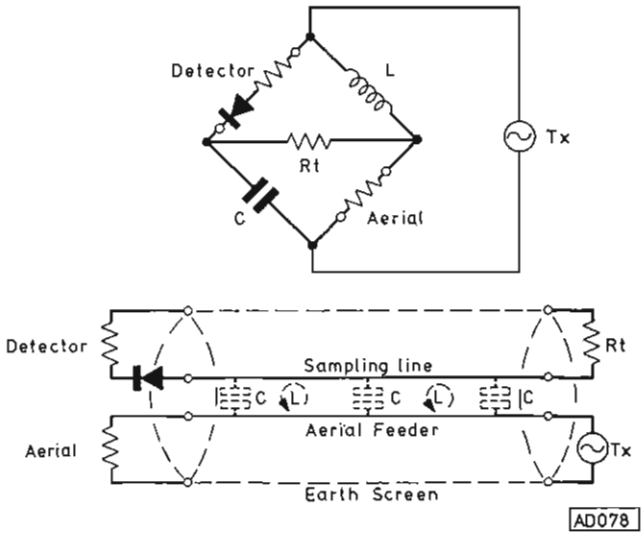


Fig. 1: Theoretical diagram of the Maxwell Bridge transmission line coupler

Circuit Description

An s.w.r. bridge works by sampling the amount of power flowing in each direction along the aerial feeder. This is achieved by the use of a Maxwell bridge transmission line coupler, as shown in **Fig. 1.** The reactive arms of the bridge are formed by the distributed capacitance and mutual inductance of the coupled lines. The two sampling lines L1 and L2, shown in the circuit diagram of **Fig. 2,** are coupled to the main aerial feeder and respectively terminated at opposite ends by R1 and R2, thus providing two outputs which are proportional to the forward and reflected signals present. Diodes D1, D2 and capacitors C1, C2 convert the sampled signals to d.c. for measurement on a conventional meter M1. Potentiometer VR1 adjusts the sensitivity of the circuit and ferrite beads prevent stray r.f. pick-up in the wiring.

In practice, the bridge can be used either way round due to the symmetry of the circuit, but for convenience, SK1 is assigned to the transmitter and SK2 to the load; this allows S1 to be designated "forward" and "reflected."

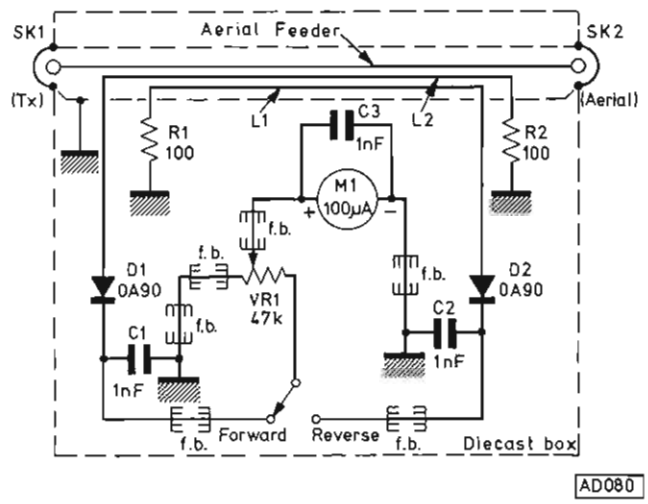


Fig. 2: Complete circuit diagram of the 2m VSWR bridge

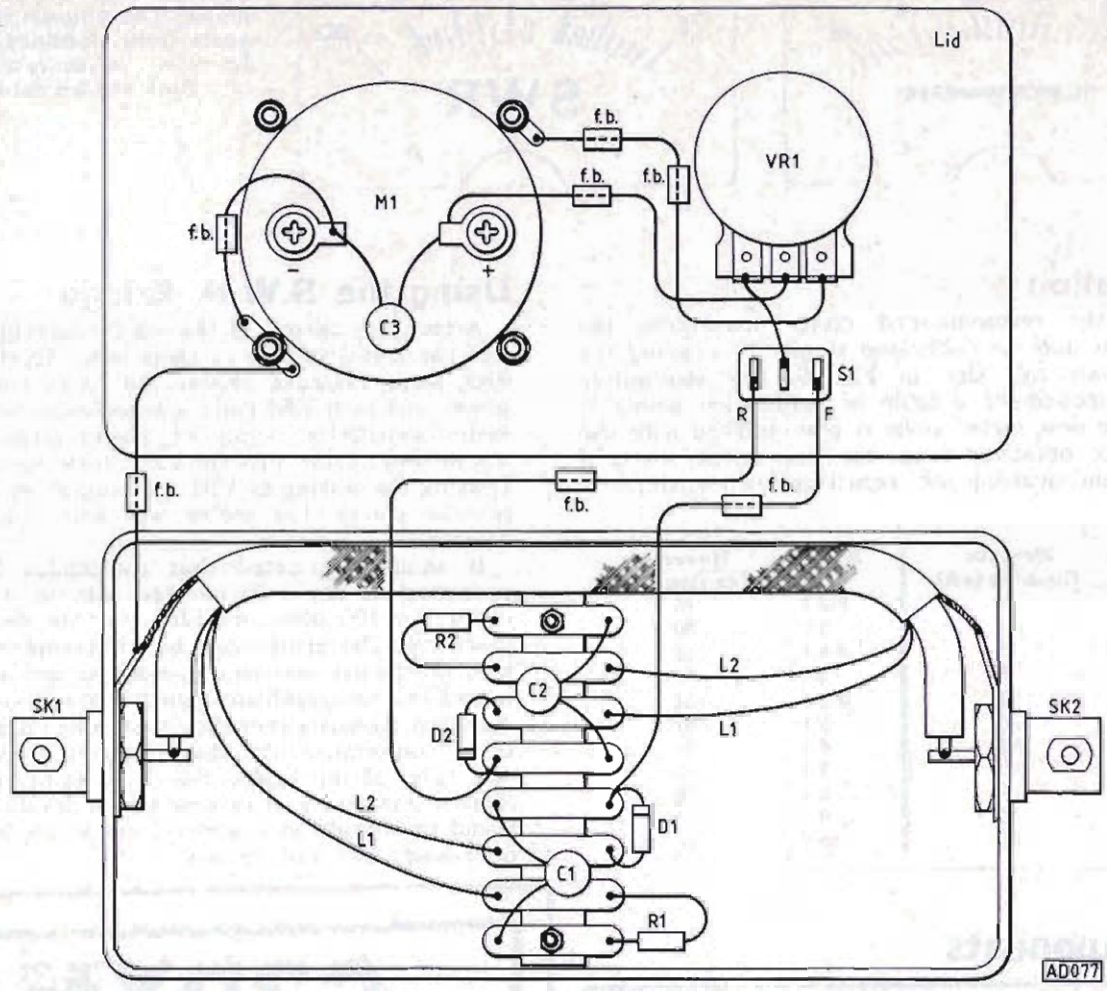


Fig. 3: Wiring layout inside the diecast box

Construction

The instrument is built into a small diecast box, which also acts as a screen. In obtaining a suitable box it is important to ensure that the depth is sufficient to provide adequate clearance for the meter movement.

The component layout is shown in **Fig. 3.** A tag strip is mounted so that the end connections are earthed via fixing screws, whilst the remaining ones are isolated: this is best done by using additional 8BA nuts to space the tag strip from the case.

It is important that the physical placement of the diodes, resistors and pickup lines is symmetrical: the better the symmetry, the better will be the electrical balance of the bridge. If matched resistors, diodes and capacitors are used, electrical balance will be even better than is possible with random-selected components. Since the bridge is essentially relative-reading, this condition, while highly desirable, is not vital for satisfactory results.

The germanium detector diodes should be matched for similar characteristics using the circuit of **Fig. 4.** A pair of diodes should be chosen such that on test there is no appreciable meter deflection as the applied voltage is varied from 0 to 9V. The meter used for evaluating the diodes should be as sensitive as possible, e.g. an Avo Model 8 on its 50μA range.

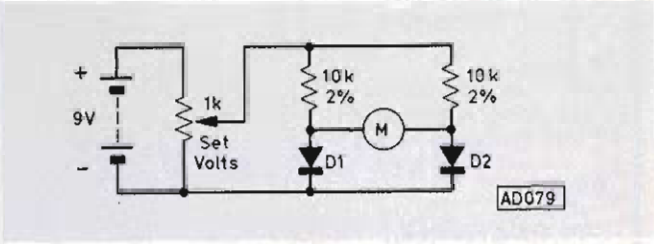


Fig. 4: Circuit used for comparing diode characteristics

The coaxial line is made from a 140mm length of low-loss coaxial cable (see component list). Its outer p.v.c. sheath should first be carefully removed and the copper braid "bunched" to allow the two sampling lines to be introduced under it. The lines should be of equal length and should be run inside the braid, with care being taken to keep them close together with no kinking. They should come out about 20mm from each end of the cable.

The accuracy of the instrument is dependent on the matching of the terminating resistors to the impedance of the sampling lines, thus the constructional details for the coaxial line should be closely followed.

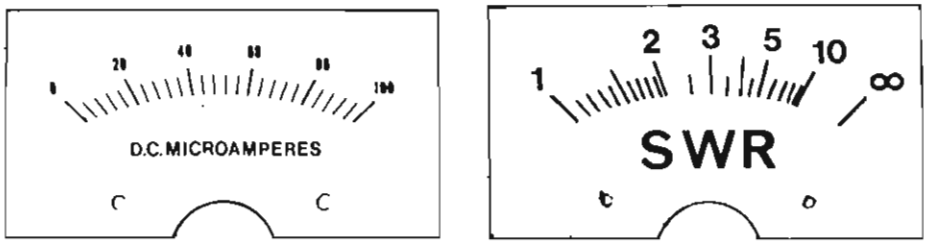


Fig. 5: Meter calibration scale for use with Maplin type '2 in PAN' meter. The original 100μA meter scale (left). Replacement scale for s.w.r. measurement (right). Both shown actual size

Calibration

Using the recommended meter movement the instrument may be calibrated simply by copying the scale shown full size in **Fig. 5.** For alternative types of movement a table of calibration points is given. The new meter scale is best marked with the scale plate detached from the movement, using a fine pen and drawing ink, pencil or dry transfers.

S.W.R.	Reverse Reading (μA)	S.W.R.	Reverse Reading (μA)
1:1	0	2·5:1	43
1·1:1	5	3:1	50
1·2:1	9	3·5:1	56
1·3:1	13	4:1	60
1·4:1	17	4·5:1	64
1·5:1	20	5:1	67
1·6:1	23	6:1	71
1·7:1	26	7:1	75
1·8:1	29	8:1	78
1·9:1	31	9:1	80
2:1	33	10:1	82

Using the S.W.R. Bridge

Attach the output of the v.h.f. transmitter to SK1 and the aerial system or some other form of load to SK2, using matched feeder. Set S1 to read forward power and turn VR1 fully anticlockwise for minimum meter sensitivity. Apply r.f. power from the transmitter and adjust VR1 for a full-scale meter reading. Leaving the setting of VR1 unchanged, set S1 to read reverse power: the meter will now indicate s.w.r. directly.

It should be noted that continuous high-power operation of the s.w.r. bridge without a load may cause the 100 ohm resistors and the diodes to be destroyed. The bridge may be left permanently inline with the feeder between transmitter and aerial, as it introduces no significant signal degradation in either direction. Constructors should be wary of placing too much importance on absolute s.w.r. readings; the real value of the bridge lies in its ability to indicate relative forward and reverse power levels. It will be found invaluable as a general aid in the adjustment of transmitters and aerials. ●

★ components

Capacitors
C1 1nF disc ceramic
C2 1nF disc ceramic
C3 1nF disc ceramic

Resistors
R1 100 ohms ¼W 2%
R2 100 ohms ¼W 2%
VR1 47kΩ linear carbon

Diodes
D1 OA90
D2 OA90 (See text)

Sockets
SK1 50Ω BNC
SK2 50Ω BNC

Lines
L1 250mm 26 s.w.g. enamelled copper wire.
L2 250mm 26 s.w.g. enamelled copper wire.
140mm low-loss 50Ω coaxial cable of capacitance 56pF/m (UR203).

Miscellaneous
Diecast box approximately 120mm × 60mm × 44mm.
100μA 2in panel meter.
Miniature single pole c/o toggle switch. Control knob with position indicator. Miniature 8-way horizontal tag strip. Earth tags, 5 required. Ferrite beads, 6 required (from TMP Electronic Supplies, Britannia Stores, Leeswood, Mold, Clwydd CH7 4SD N. Wales).

G2DYM ANTI-TVI AERIALS

New 1980 Models: Shortwave listener **Indoor** models **£14.50 & £27.50. Outdoor** models **£30.00 & £36.00.**

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G2DYM, UPLOWMAN, TIVERTON, DEVON.

ADD-ON RECEIVER ACCESSORIES

ERIC DOWDESWELL G4AR

The short-wave listener with his first communications receiver cannot be expected to get the best from it until a fair amount of time has been spent listening and getting the feel of the set, and of s.w. propagation conditions. There will be a tendency to cast an eye on the ads in various radio magazines for add-on accessories which claim to give improved reception.

Whether they will or not much depends upon the receiver. If it is from the highest price bracket it is very unlikely that much can be done externally to improve it. Indeed, any additions would be an insult to the designer! If, however, the set is really basic, without an r.f. stage and only simple ceramic filters in the i.f. stage/s and a conventional audio output stage, then it is going to need all the help it can get.

This article sums up the pros and cons of add-on units because they make excellent DIY projects and most can be bought in kit form or ready-built. But, remember, all of them, except a passive audio filter, will add some noise to the normal noise of the set. What we want is less noise and more signal and the simplest way of achieving that is probably cheapest. A better aerial system! Add-on units fit the bill because they restrict the bandwidth being amplified, at the r.f. input, at the i.f. stage or in the audio circuits.

Preselectors

A common tendency, where a listener considers that signals ought to be stronger, is to add a preselector (sometimes referred to as a pre-amplifier, wrongly in my opinion, as this term is usually reserved for audio work). If the receiver already has one or more r.f. stages then the preselector may prove to be worse than useless, causing increased cross-modulation, especially where strong signals are concerned. If the set has no r.f. stage at all then a preselector will be very worthwhile.

When obtaining a preselector make sure that it is a tuneable one and not aperiodic (wideband) and that it covers the s.w. bands on the receiver with which it is to be used. It must be connected to the receiver with proper coaxial cable, such as that used on TV installations, using proper coaxial fittings as it is essential that the signals reach the receiver via the preselector and not through any unscreened wire connected to the aerial terminal of the set.

The band switch should include a position where the aerial is switched directly to the receiver, eliminating the preselector and, generally, turning off the power supply to the preselector. Not an essential feature but highly desirable. An r.f. gain control is essential but if one is not fitted it is an easy matter to modify the preselector.

When using the preselector, first switch it to the straight-through position and tune the set to a steady but not too strong signal in, say, the 19m band, with the set's r.f. gain about half way. Switch in the preselector on the appropriate range and tune it for an increase in signal strength, which should be very marked. Note if there are any spurious signals that were not on the original signal. If there are this is a sign of internally generated cross-modulation and the r.f. gain on the preselector should be reduced until the spurious signals disappear.

Always ensure that the preselector is tuned "on the nose" to any signal being received and **never** detune it to act as a volume control. If a calibrated dial is fitted check that the frequency at which it peaks corresponds, more or less, to the signal frequency. At the higher frequencies it is very easy to tune the preselector to the second channel frequency which produces a marked increase in noise but no increase in wanted signal strength.

If, for example, the wanted signal is on 15050kHz then the second channel frequency is 15050kHz plus twice the set's i.f., usually around 470kHz, making 15990kHz which is not so far removed, as far as the tuned circuit is concerned, from 15050kHz. Many a preselector has been condemned because it has been tuned wrongly.

A preselector is sometimes chosen because it is thought that it will improve the "selectivity" of a receiver. This refers to the problem of adjacent channel selectivity where the preselector cannot help to any marked degree, but it does greatly reduce the second channel interference, previously referred to, by introducing more tuned circuits at the signal frequency.

Preselectors tend to be of more use at the higher frequencies especially if the main receiver is an older one lacking in sensitivity at the h.f. end. Do not be afraid to switch the preselector in and out of circuit to see if it is really effective. Sometimes it will be found to be an improvement and sometimes not, much depending upon the frequency involved.

Q-Multipliers

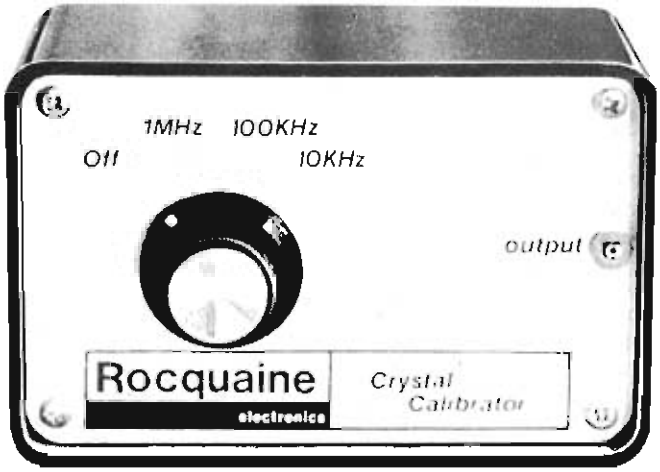
Adjacent channel selectivity is the main failing of most communication receivers, especially the cheaper variety, and, come to think of it, the not-so-cheap ones now available. Selectivity is governed entirely by the quality of the i.f. filters, generally the one immediately following the mixer stage. Ceramic filters are frequently extolled today as being the best, but only because they are cheaper for the set manufacturer and eliminate expensive alignment time. The three usual modes of reception in which we are interested, a.m., a.m.(s.s.b.) and c.w. all require different i.f. bandwidths for optimum reception and a single bandwidth i.f. filter can only be a compromise. Unfortunately, separate filters can make a receiver rather expensive.

The only external aid to improved i.f. selectivity is some form of "Q-multiplier" which can be wired into the set with a couple of screened leads and virtually no modification to the set itself. In effect it extracts some of the i.f. signal and passes it through the external i.f. stage and back into the set. The external stage, or Q-multiplier, has a feedback control which allows the bandwidth to be sharpened up thus improving the selectivity, often to the point where the multiplier goes into oscillation. It only peaks signals over a comparatively narrow band of frequencies, rather than producing the ideal square-topped bandwidth characteristic, but it can be very effective for c.w. reception.

When buying or making a Q-multiplier ensure that its operating frequency is the same as that of the set to which it is going to be fitted. There is usually some form of adjustment to peak it to the i.f. after installation. Like the preselector there should be an "off" position that effectively by-passes the Q-multiplier.

Calibrators

No receiver should be used without some means of checking its calibration instantly. The better sets will have an internal crystal oscillator operating on 100kHz producing markers at that interval throughout the s.w. bands. Sets intended for the US market may have this broken down to 25kHz for checking the limits of the mandatory sub-bands in that country.



Rocquaine Electronics produce this crystal calibrator, an important accessory for a communications receiver

My own preference is for an external 1MHz crystal oscillator divided down to provide outputs at 100kHz and 10kHz, in addition to the fundamental 1MHz. After that it is not difficult to interpolate down to 1kHz especially if there is a decent bandspread dial on the receiver, which is quite sufficient to pinpoint an amateur or broadcast station for reference purposes.

The output of the calibrator is inserted into the set at the aerial terminal, again using coaxial cable. If possible fit a three-way wafer switch to provide "aerial only", "aerial plus calibrator" and "calibrator only". If the aerial is permanently connected then marker signals can often be lost or difficult to locate among other signals.

DFM from Roquaine Electronics operates up to 40MHz. It can be coupled to the receiver to provide direct readout of frequency. Unusually, wavelength can also be displayed

It is desirable for the receiver to have some means of either moving the dial cursor line or the frequency of the local oscillator in order to bring the set's calibration into line on any range. A small value tuning capacitor is often used in parallel with the oscillator section of the ganged tuning capacitor or an additional potentiometer if the oscillator is varicap tuned. Then the nearest calibration point on the dial can be made to agree with a marker signal from the calibrator, around the frequency of the station being checked.

My own method of measuring a station's frequency is to first note the approximate frequency and then check the 100kHz points on the set's dial against the calibrator, either side of the station, adjusting the vernier control if necessary to make the dial and calibrator agree. Then the 10kHz markers are switched on and counted down or up from one of the 100kHz markers. The station finishes up between two 10kHz points after which the frequency can be estimated to about a kilohertz. Sounds longwinded but, in fact, can be done in seconds, with some practice.

Note that all the usual causes of frequency drift in a set such as mains variations, temperature changes, vibration, etc., are eliminated by checking against a crystal standard over a very short period of some seconds only. Some experts recommend the preparation of calibration charts for every range of a receiver, checking every 100kHz point against the standard and noting the difference. This is an extremely tedious and entirely unnecessary procedure and certainly unreliable. A heavy knock or an enforced repair to the set and all the work done in preparing the graphs has gone down the drain, apart from the uncertainty of all the other factors previously noted.

One more point to watch. Ensure that the signal is tuned in for maximum strength, preferably using the S-meter if one is fitted, rather than relying upon the ear. The beat frequency oscillator should be used when making these frequency measurements and must be correctly adjusted and checked again from time to time.

To set the b.f.o., turn it off, tune in a reasonably strong signal, on the m.w. band if possible, where it is more likely to be steady in strength, again using the S-meter, then switch on the b.f.o. and adjust the beat frequency to zero. This point should coincide with the datum point on the b.f.o. knob or dial. Now, if it doesn't, either mark the zero-beat point on the panel or set the knob to the datum point and adjust the frequency of the b.f.o. internally until the zero-

beat agrees with the datum. Either way, it is essential to know when the b.f.o. is zero-beat and it must be set at that point whenever a frequency measurement is to be made. A marker from the crystal calibrator can be used, in lieu of a station, in making this adjustment.

Audio Filters

Audio filters are a common way of increasing the adjacent selectivity of a receiver but the importance of obtaining adequate selectivity as early as possible in the receiver cannot be overemphasised, thus giving subsequent filters a better chance of doing their job and avoiding the overloading of stages by strong signals.

The average audio stage is pretty flat in response compared to what is really required, especially on the amateur bands. The vast majority of amateurs use s.s.b. with commercial equipment where the audio bandwidth is deliberately restricted to about 300 to 3000Hz, considered the minimum necessary for adequate intelligibility on speech. So it is pointless for the audio stages to be any better than this, unless the SWL is particularly interested in the broadcast bands where better quality audio may be desirable.

On c.w. the bandwidth should be very sharp indeed and bandwidths down to a few tens of hertz are common although a couple of less selective positions are advisable. A simple way to restrict audio bandwidth is to fit an external filter between the set and the headphones. Commercial filters available may offer switchable bandwidths of, say, 80, 110 and 180Hz which are a joy to use on c.w. However, given the choice, such a filter should be fitted immediately after the detector stage and before the first audio stage, where signal levels are low, if it is to give of its best.

Some audio filters are passive, that is they do not contain any amplifying device, but consist of inductors and capacitors to resonate at, say, 750Hz or so. These will not provide such narrow bandwidths as previously quoted without "ringing", an effect that causes notes from c.w. signals to be sustained so that at high speeds the dots and dashes merge making the signal unreadable.

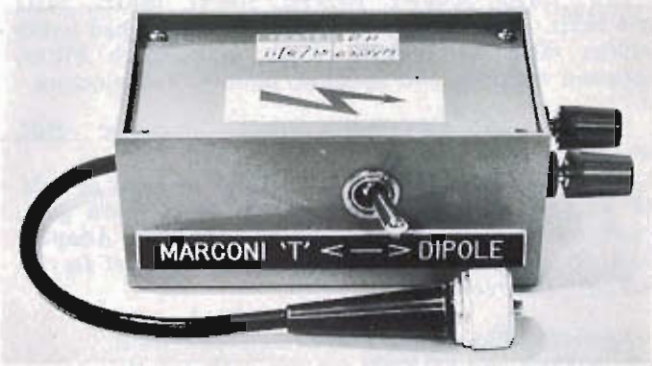
Although I have mentioned headphones before in other articles I am not going to miss the opportunity to do so again! They are an extremely important part of the receiving set-up. Not a luxury, but an absolute necessity for the serious DXer, to be preferred to a speaker at all times, unless listening to Capital Radio while doing some other work in the shack!

To go back a bit in time, the old magnetic diaphragm type of headset had a high resistance of 2 to 4kΩ, was extremely sensitive and frequently formed the anode load of the detector or first audio stage. No further amplification was necessary, hence the popularity and great sensitivity of the old t.r.f. receivers. These headsets had a very peaky response, frequently with a peak around 1000Hz, thus forming an excellent mechanical filter in themselves. When the c.w. beat note was adjusted to the same frequency the result was quite startling!

These old headphones had little response at low frequencies so any hum on the power supply was completely attenuated. In all, every desirable feature for the DXer. But along came hi-fi and stereo and low impedance headsets with every undesirable characteristic as far as DXing is concerned! If you can find a pair of high impedance headphones try connecting them to the receiver's low impedance output with a transistor type step-up audio transformer. An old valve-type output transformer is ideal.

Aerial Tuners

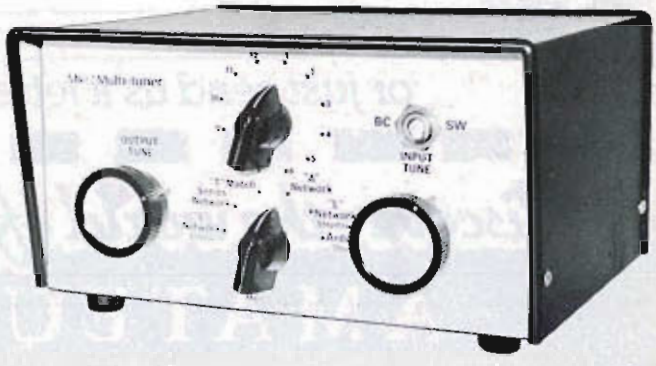
The best receiver going will do even better if it is allowed to, by providing it with a good aerial system suitable for the frequency band in use, as distinct from an odd length of wire. Any aerial can be likened to a tuned circuit where the voltage developed across the circuit is at a maximum when it has the same resonant frequency as the incoming signal. An odd length of wire will be resonant at some frequency or other but an aerial tuning unit (a.t.u.) will ensure that it is resonant at the desired frequency at all times.



A ferrite-cored transformer is used in this wideband aerial matching unit by G2DYM Aerials and Projects

An a.t.u. can be bought or it makes an ideal home project, because a simple a.t.u. need only consist of a tapped coil and a tuning capacitor initially. A more comprehensive one would have another capacitor and calibrated knobs plus a wafer switch to select the appropriate tap on the coil. An a.t.u. is simply an r.f. transformer changing the impedance at the end of the aerial wire to that of the input impedance of the receiver.

When using an a.t.u. the aerial is connected to the input terminal or socket and the output goes, via a short length of coaxial cable, to the aerial and earth terminals of the receiver. Most receivers today have a low impedance input, 50 to 75Ω, so the a.t.u. will take care of the mismatch between aerial and set.



This a.t.u. from Stephen-James allows any length of aerial to be resonated on the h.f. amateur bands. It also covers the m.w. broadcast band

In use, the object is to find the right amount of inductance, by changing the tapping point on the coil, and the correct amount of capacitance, the point of resonance being indicated by a sharp increase in signal strength. There will be many points at which the signal will peak but there will be a particular ratio of inductance and capacitance giving the maximum signal. Make a note of the tapping point on the coil and the tuning capacitor/s settings for future reference. Do this at the centre of each band of interest. It is worth while taking a little time to find the correct settings, so do not settle for the first peak found.

Stephen-James Ltd, 47 Warrington Road, Leigh, Lancs.
Multi Tuners, Mk1 1·8 to 30MHz, five aerial configurations. Mk2, similar plus m.w. band. **Crystal Calibrator,** 1MHz, 500kHz, 100kHz, 50kHz, 10kHz, 5kHz and 1kHz. **Audio Bandpass Filter,** eight switched bandwidths 80Hz to 2·5kHz. Peak and Notch Filter, between receiver and speaker/phones. Preselectors.

Amtest, 55 Vauxhall Street, Rainbow Hill, Worcester WR3 8PA.
Aerial Tuner AT2, 1·5 to 30MHz for end-fed aerials: **RF Preselector** PRS1, same range, up to 30dB gain. **PRM** for m.w. coverage to 1·6MHz. **PRM Adaptor Unit,** for coupling external aerials to internal ferrite rod aerial of receiver.

Partridge Electronics Ltd, Broadstairs, Kent.
ATU's 111B and LO-Z500 for use with Joystick aerial. **Joymatch Triple purpose ATU,** s.w. and m.w. coverage, in kit form.

Cambridge Kits, 45(P) Old School Lane, Milton, Cambridge CB4 4BS.
LF Converter, 100/600kHz converted to 80m band. **Tunable Audio Notch Filter,** between speaker and receiver, 350 to 6000Hz. **Crystal Calibrator** 1MHz, 100kHz, 25kHz. All are kits.

G2DYM Aerials and Projects, Whiteball, Wellington, Somerset.
Aerial Matching Unit, designed to combat TV timebase QRM, untuned, wideband for 50Ω to balanced feeder from multi- or single-band dipole. Switch for Marconi T operation on 160m and broadcast band.

Lowe Electronics Ltd, 119 Cavendish Road, Matlock, Derbyshire.
ATU, Daiwa CL22 1·8 to 30MHz for SWL. **Converters** by Microwave Modules, various for 4m, 2m, 70cm and 23cm to h.f. receiver.

Rocquaine Electronics, Aldebaran, Le Coudre, St. Pierre-du-Bois, Guernsey, Channel Isles.
Crystal Calibrator RQ1, 1MHz, 100kHz and 10kHz, c.w. or modulated output, kit form. **Frequency Counter** RQ3, up to 40MHz, 4-digit l.e.d. display of frequency or period or wavelength, kit form.

Datong Electronics Ltd, Spence Mills, Mill Lane, Bramley, Leeds LS13 3HE.
Active Antenna AD170, indoor aerial system 60kHz to 70MHz, 3m long dipole plus amplifier, output 50Ω. **Up-Converter UC/1,** synthesised receiving adapter plus 2m converter for receivers tuning 28-29MHz or 144-145MHz, range 90kHz to 30MHz. **Audio Filter FL1,** automatic suppression of heterodynes in range 280-3000Hz, variable width notch 25-1000Hz. ●

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AERIAL DESIGN
using scale models

Fred JUDD G2BCX

Much of the initial development work on the "Slim Jim" and ZL series of 2 metre aerials recently described in *PW* (May 1977, April 1978, November 1978) was carried out with the aid of a u.h.f. scale-model aerial performance testing system. This was dealt with in *PW* in January 1978, but has since been much modified with the addition of a visual polar pattern display derived from a surplus 10in radar PPI unit as shown in Fig. 1. Because the above issue of *PW* is now out of print I will again, but briefly, deal with the method of employing ultra high frequency scale models as an aid to the design of aerials as well as performance measurement.

Similar aerials behave in exactly the same way, i.e., they will have the same gain and radiation pattern etc. whether operating at h.f. or u.h.f., so it is possible, for example, to scale down a typical beam aerial intended for operation at, say 28MHz to a small but easily handled model operated at around 500 to 700MHz. At frequencies much higher than this, matching the aerial to a feed cable and the transmitter becomes difficult.

Accurate matching is very important if gain is to be measured but is of little consequence if only radiation patterns are to be demonstrated. A mismatch between feed cable and aerial will not normally affect the radiation pattern, although wrong phasing between coupled radiating elements, such as in colinear arrays, will cause severe pattern distortion.

Transmitter

The first requirement is a "transmitter" which may in fact be a simple self-excited oscillator capable of delivering a few watts of power. Frequency stability is not greatly important as the model aerial to be tested is operated in "receive" mode, and the receiver itself need only be a tuned circuit with a diode rectifier, so as to obtain a rectified (d.c.) signal from the aerial. The distance between the transmitting aerial and the aerial being tested should not be less than about 10 wavelengths at the frequency used, e.g. at 600 MHz this would be about 5 metres (50cm per wavelength).

A circuit of a typical quarter-wavelength line oscillator suitable for a transmitter is shown in Fig. 2. The valve (V) may be any u.h.f. triode with appropriate power rating (on average the r.f. power output will be about 30 to 40 per cent of the d.c. power input). Tone modulation can be obtained by feeding an audio signal of a few volts to the grid via the 100kΩ resistor as shown, although this is only necessary if the model aerial system is to be used for demonstration so that signal variation can be made audible. The transmitting aerial may be a dipole but it is better with a plane reflector as shown in Fig. 3, which will increase the radiated power and confine it to one direction.

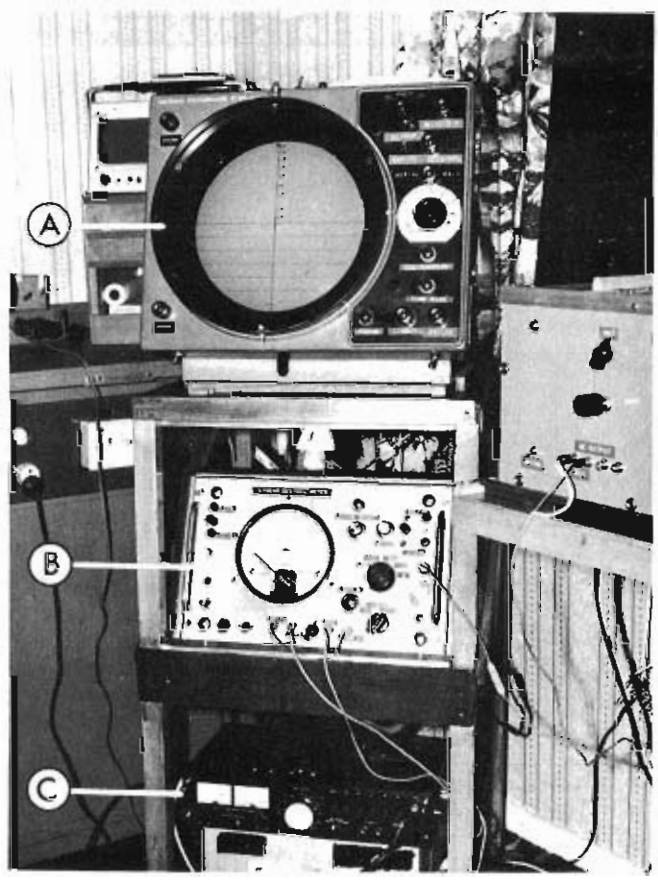


Fig. 1: The author's aerial test console, showing: (A) The PPI (polar pattern indicator) display (B) The linear reading decibel meter (C) Magnetic tape recorder. See text

Polar Pattern Indicator

It so happens that "PPI" stands equally for polar pattern indicator or for its original designation in radar, namely, plan position indicator. The display shown at (A) in the photograph Fig. 1 is in fact a converted marine radar unit. Rebuilt might be a better word, as all the original electronics was stripped out and replaced by solid-state circuitry to provide the special facilities required, as illustrated in the block diagram Fig. 4. The display c.r.t. is 10 inches in diameter and the tube is a long-persistence

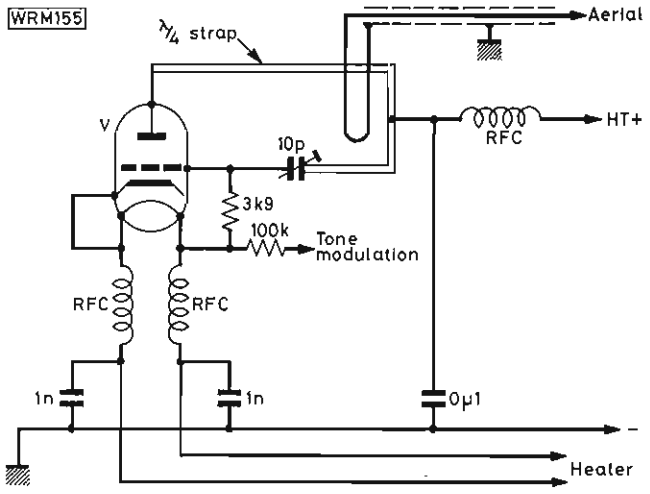


Fig. 2: Suggested circuit for a simple v.h.f. oscillator for use as a transmitter. See text

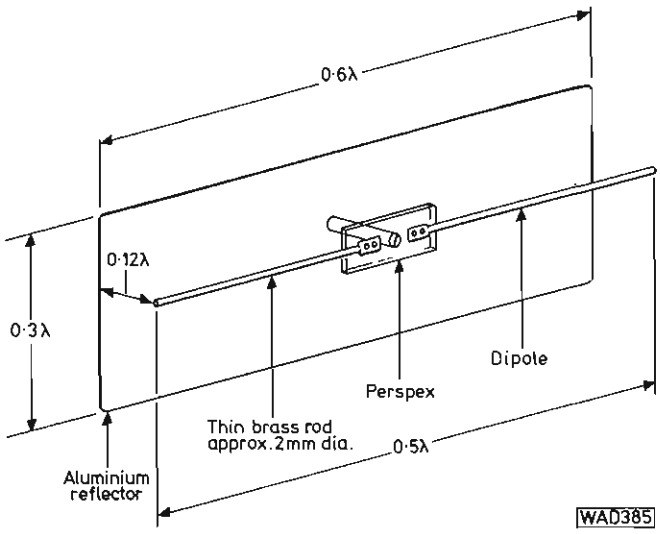


Fig. 3: Aerial for the transmitter, consisting of a dipole with a plane reflector

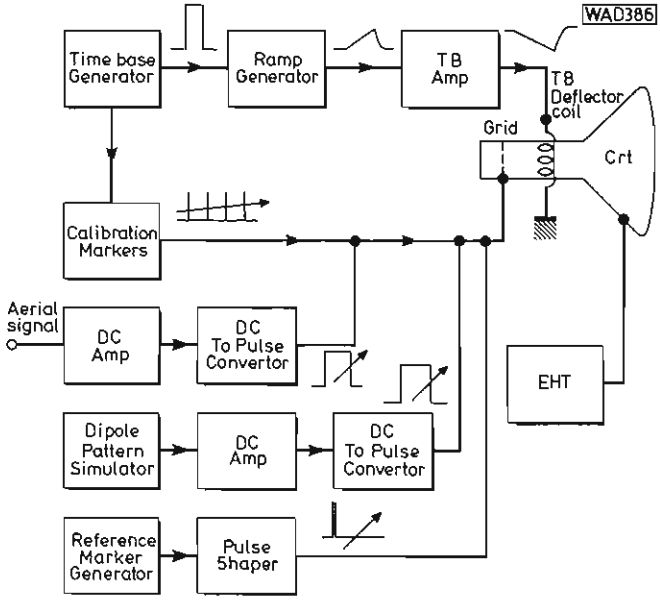
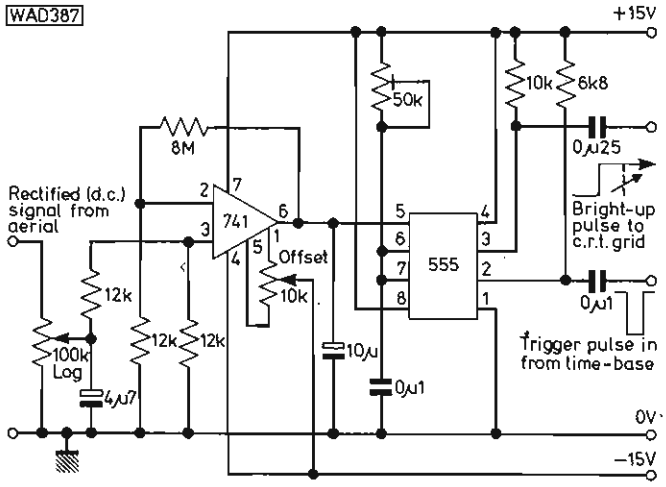


Fig. 4: Block diagram of the polar pattern indicator

Fig. 5: Circuit for converting varying d.c. (rectified r.f.)



type. The timebase deflector coils are motor-driven at one rotation per 3 seconds and the timebase repetition rate is 360Hz, so that in one complete rotation the timebase makes 1080 sweeps.

The signal from the aerial is d.c. (rectified r.f.) and this varies according to the radiation pattern. However, this d.c. signal is converted by the circuit shown in Fig. 5 to a variable-width square pulse which is used to brighten the trace. The amplitude of signal from the aerial is therefore displayed as a bright line every third of a degree. Since the model antenna rotating system is synchronised to the PPI display, the radiation pattern is continuously displayed as a stationary picture. Aerial signal amplitude is also measured by a direct-reading decibel meter (B), seen beneath the display, and this unit also incorporates special circuitry for converting the varying d.c. aerial signal to a correspondingly varying amplitude sinewave at 2000Hz that can be recorded on magnetic tape (C). These signals are demodulated for display on the PPI at another time. In other words, all patterns displayed on the PPI can be tape recorded for reference and displayed again whenever required.

The PPI display has a number of other facilities, such as the "electronic reference dipole" which produces a perfect cosine pattern to any desired amplitude, and there is provision for an electronically produced omni-directional pattern, which can also be set to any amplitude. Other facilities are: fixed calibration markers for linear voltage or linear dB readout and variable marker for establishing amplitude reference or 3dB points on the displayed radiation patterns. The display is equipped with colour filters for photography and also map screens so that patterns can be viewed more realistically with regard to coverage over a given area. The system readout accuracy is to within ±1 degree on angles associated with displayed patterns and to within ± 0·5dB on amplitude.

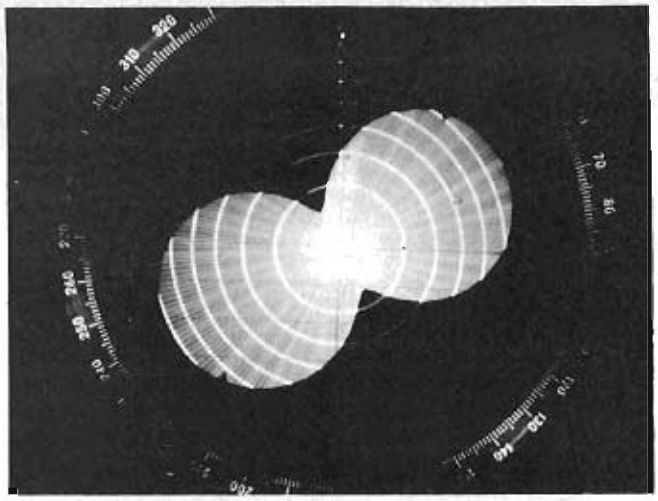


Fig. 6: Electronically generated reference dipole pattern with superimposed amplitude calibration markers

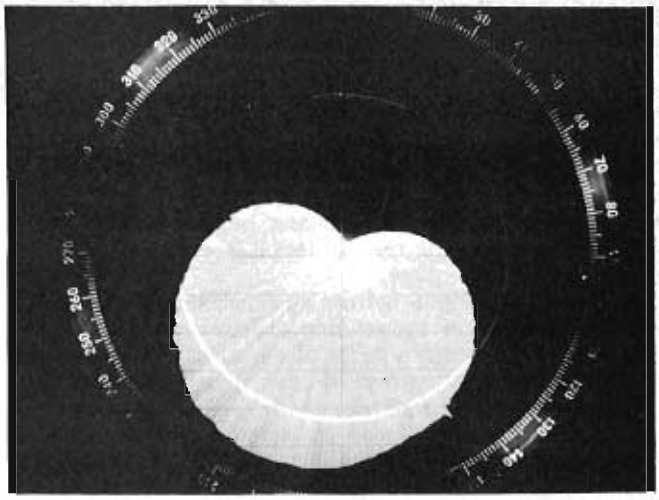


Fig. 8: Radiation pattern (cardioid) of a two-element ZL beam in vertical mode, with 3dB marker ring

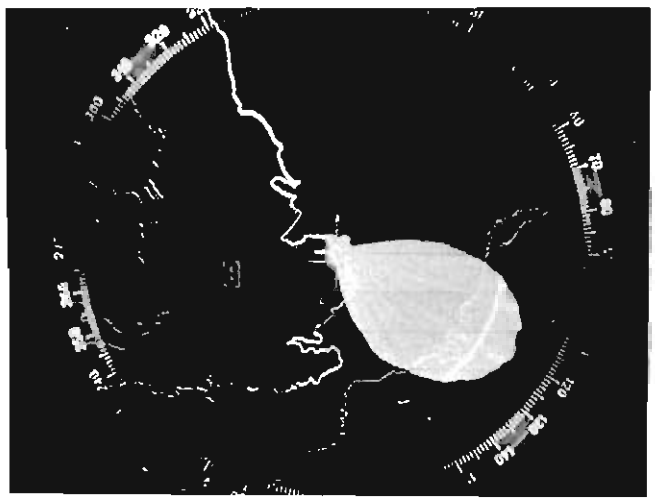


Fig. 7: Polar pattern of a two-element ZL beam in horizontal mode with map overlay. Display centre is based on the writer's QTH in Norfolk

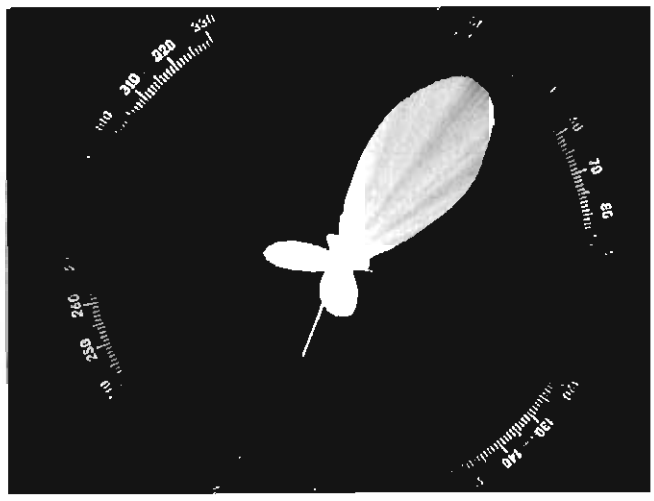


Fig. 9: Pattern from an experimental high-gain beam aerial, which shows that side lobes are too large and therefore the design is not acceptable

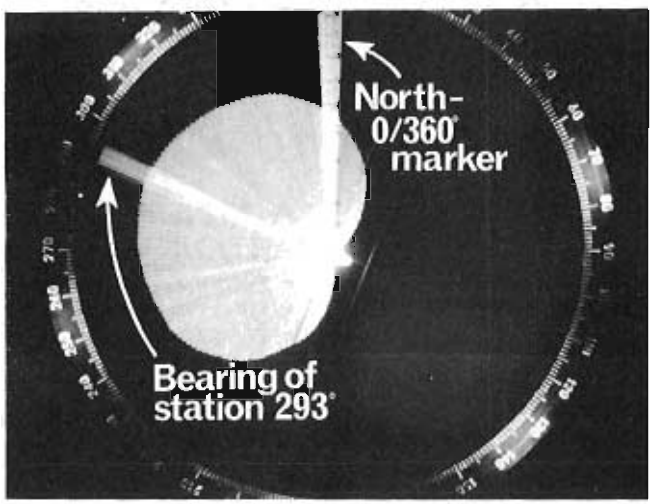


Fig. 10: The PPI display can be used for v.h.f. direction finding in conjunction with a continuously rotating aerial. See text regarding bearing markers

The photographs Figs. 6–10 were taken with a Polaroid 350 camera, using a lens aperture of about f/16 and exposure time equivalent to one rotation of the timebase, i.e. about 3 seconds. The facilities of the display are illustrated as well as actual patterns from model aerials and the captions provide a short explanation of each photo. The pattern of the 2-element ZL Special in vertical mode (Fig. 8) may be of particular interest to users of this aerial, as it has a virtually perfect cardioid shape which makes it very suitable for v.h.f. direction finding because of the very well-defined null to the rear. In fact it is used by a certain authority for this purpose.

The pattern in Fig. 9 is from an experimental high-gain beam aerial using a square-loop radiator, a square-loop parasitic reflector and a series of parasitic directors. The square-loop reflector proved to be inefficient, however, as is the case with Quad aerials, owing to the large lobes to the rear. This was replaced by a larger plane reflector which almost completely eliminated the spurious lobes and provided a greater forward gain.

Experimental work of this nature can be carried out very rapidly with scale models, in conjunction with the PPI display described in the foregoing paragraphs. This set-up has been put to good use in the design and development of numerous v.h.f. aerials, some of which *PW* readers are already familiar with, the latest being a colinear version of the "Slim Jim" which it is hoped to publish shortly.

Direction Finding

The PPI display can also be used in conjunction with full-size 2 metre aerials, not only for performance measurement etc., but for direction finding as well. It can be coupled to an aerial that rotates continuously in synchronism with the rotation of the timebase. The signals from the aerial are taken to a sensing circuit that provides a short duration squarewave when the signal from a particular direction is at maximum amplitude. The bright arc produced on the display by this squarewave is about 5 degrees wide and its centre denotes the actual bearing. A similar bright arc is produced for a "north" or 0/360 degree reference. The photo in Fig. 10 shows an actual readout from a station bearing 290 degrees with respect to north or 0/360 degrees. Directions of stations obtained with this system are to within better than 2 degrees and a bearing can be registered even if a signal is present for only 5 or 6 seconds. Continuous rotation of the aerial is obtained by an inductive loop coupling method devised by the author, and which with continued development, may prove to be the means of achieving a low-cost beam aerial rotation system. ●

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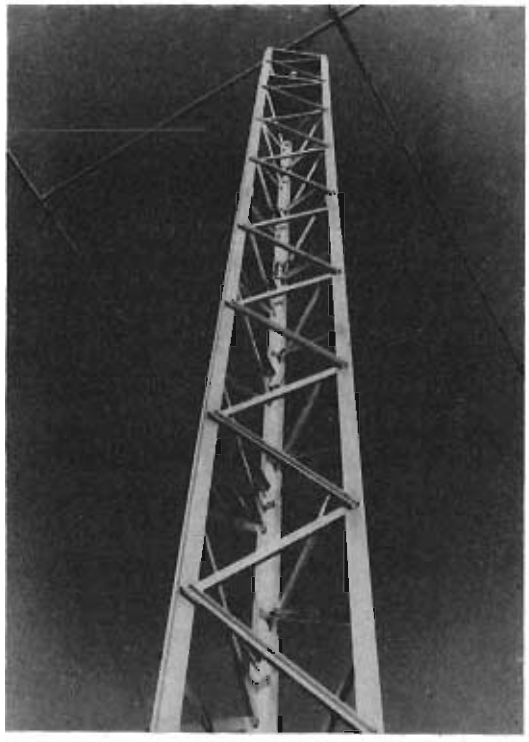

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REMOTE AERIAL PRE-AMP SUPPLY

There have been several published designs for remote (mast-head) aerial pre-amplifiers, but these have generally been battery powered, or fed via a separate supply cable. It is very convenient, and not difficult, to supply power via the signal coaxial cable, using the circuitry shown here to draw power from the associated tuner.

In Fig. 1, C1 isolates the d.c. supply from the pre-amp output, and L1 prevents the r.f. output from being shunted away via the pre-amp power supply circuits. Resistor R_x is chosen to reduce the supply voltage to the required value at the rated current consumption of the pre-amplifier, and also provides supply decoupling in conjunction with C2.

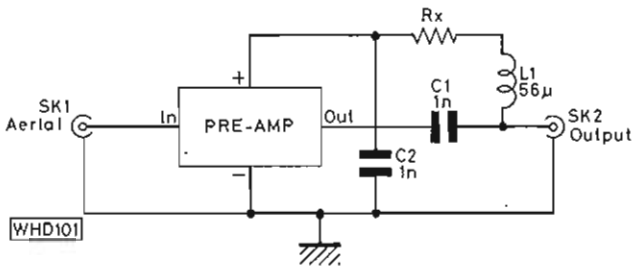


Fig. 1

To prevent damage to the tuner's power supply, in the event of a short-circuit on the aerial downlead, some sort of overload protection is necessary. The circuit of Fig. 2 is fed from the power supply reservoir capacitor, which will often have around +15/25V on it. The series pass transistor Tr1 acts as the control element of the overload protection circuit, and also provides electronic smoothing by the action of R1, C3, R2. When an excessive current is drawn, the voltage drop across R4 will rise above about 0·6V, turning on Tr2, whose collector current triggers CSR1. When CSR1 conducts, it removes the base drive from Tr1 and so shuts off the d.c. supply to the tuner aerial socket via D1 and L2. The supply is restored by pressing S1, the "Reset" button. Diode D1 protects Tr1 from high reverse emitter-base voltages which can occur at switch-off if there is a large-value capacitor in the aerial pre-amplifier. Decoupling is provided by L2 and C4. Capacitor C_y must be added to the tuner input circuit if the latter is not a d.c. open circuit.

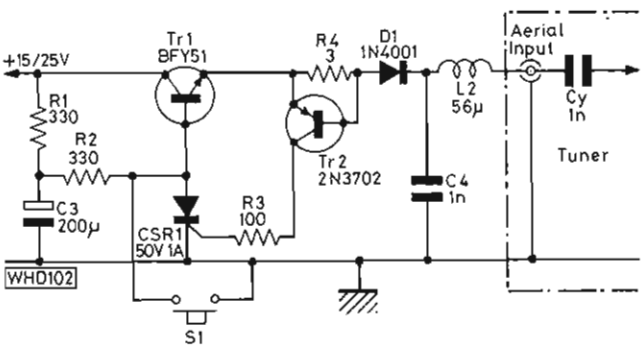


Fig. 2

The output voltage of the protection circuit will be about 1·5V less than the tuner supply voltage, due to the voltage dropped across Tr1, R4 and D1. With the value shown for R4, shutdown will occur at a load current of about 200mA. If some other value is required (dictated by the maximum safe additional current which can be drawn from the tuner power supply), the value of R4 can be calculated from the formula:

$$R4 = 0{\cdot}6/I_c$$

where R4 is in **ohms** and I_c is in **amps.**

The inductors L1 and L2 should be mounted as close as possible to the coaxial sockets, and may be made by winding about five turns of enamelled copper wire onto a ferrite bead. Other than this, the circuit layout is in no way critical.

P. J. H. Fox
Oxford

MW/LW LOOP AERIALS

Charles MOLLOY G8BUS

It has been said that more broadcasting takes place on the medium waves than on all of the short wave bands put together. There are literally thousands of stations throughout the world operating on frequencies between 535kHz and 1605kHz. The latest counts reveal over 4000 in the United States alone! Inevitably this means frequency sharing, with many simultaneous broadcasts on a single channel, and the problem confronting the m.w. DXer is: how do I deal with co-channel interference?

The receiver cannot do it. Selectivity is the ability to select stations that are on different frequencies, so the problem does seem insoluble. Often it is. If, however, two stations on the same frequency lie in different directions from the DXer's QTH, it ought to be possible to separate them with a directional aerial. The internal ferrite rod aerial used in portable receivers is directional. Tune round the medium waves after dark until you come across two stations jumbled up together. Rotate the receiver about its vertical axis and you may find that you can listen to one station on its own with the receiver in one position and to the other station alone, with the receiver in another position. It is quite a fascinating exercise: anyone interested in "local radio" DXing should try it.

A ferrite rod aerial does not pick up enough signal to satisfy the m.w. DXer, so the m.w. loop has been developed (Fig. 1). It has a pick-up somewhere between that of a long wire and a ferrite rod aerial.

How does it Work?

Imagine a single-turn loop placed vertically so that its plane is broadside-on to an incoming signal. The wavefront will strike both vertical wires simultaneously, and equal, in-phase voltages will be indueed in them, i.e. when the top of one vertical wire is positive then the top of the other will also be positive (Fig. 2). These two voltages are in opposition! Trace the path round the loop and you will find − + + −, so the net voltage applied to a receiver would be zero. This is the position of minimum pick-up, the null.

Now turn the loop through 90 degrees, so that the two vertical wires are in-line with the transmitter. The wavefront will strike the nearer of the two verticals before it reaehes the second. There will be a phase difference; unequal voltages (at any instant) will appear across the two verticals and the difference between them is signal available to be applied to the receiver. This is the position of maximum pick-up.

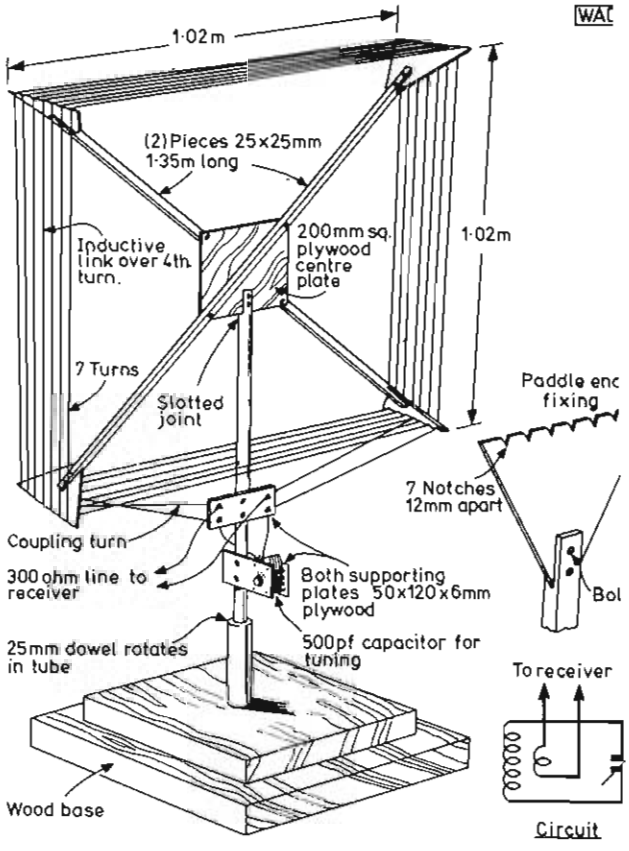


Fig. 1: Constructional details of the standard "4 inch" box loop for medium wave use, wit corresponding theoretical circuit

A loop follows a cosine law. $V = V_{max} \cos \theta$ where = the angle between the direction of maximum pick-u and the direction the loop is actually pointing. V equa the signal pick-up from that direction. It is easy to pl a curve called a figure-of-eight (Fig. 3) using this formul The loop is at the centre of the figure-of-eight and tl distance from it to the curve is proportional to the sign pick-up in that direction.

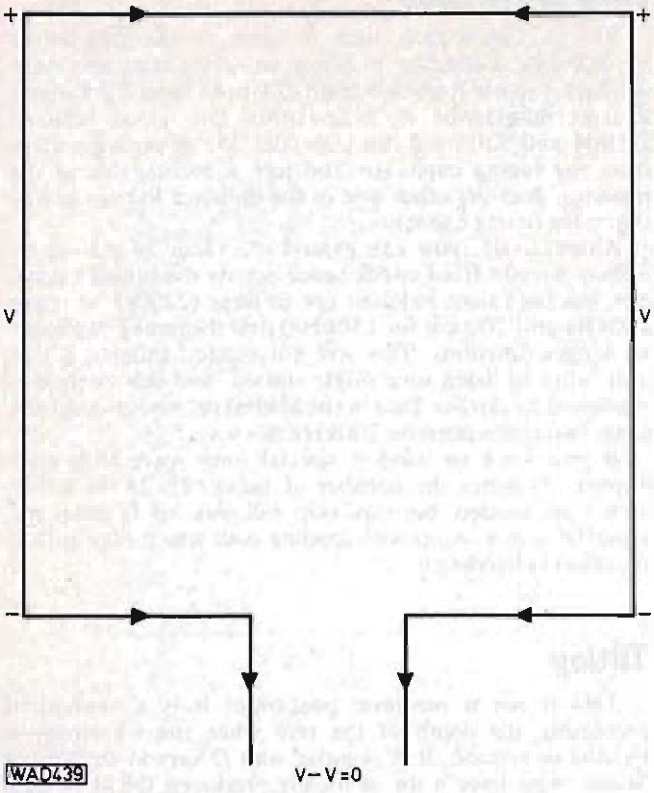


Fig. 2: Voltages induced in a single-turn loop, broadside-on to the transmitter, cancel to produce a null output

From this figure-of-eight polar diagram, two important features of a loop emerge:

a) The null is sharp while the maximum is broad. A loop is used to null-out QRM. It is the null that matters, not the maximum.

b) There are two nulls spaced 180 degrees apart. The loop will not null-out QRM coming from the opposite direction to the DX. It will null-out both of them together, which is not very helpful.

The Standard "40 inch" Loop

DXers in the UK have, after a lot of experimenting, produced the "40 inch" box loop shown in Fig. 1. It is a compromise between convenience and electrical performance. There are **two** windings. The main winding consists of seven turns, the two ends going to the tuning capacitor to form a tuned circuit. The second winding, which is a single turn, is wound next to the centre turn of the main winding and it picks up signal from the main winding by induction. This signal is then led off to the receiver.

The wire used for both windings is 22 s.w.g. single-conductor, plastic-covered copper wire known as hook-up or connecting wire and approximately 34m of it is required. It is desirable to use balanced feeder to connect the coupling winding to the receiver. My preference is for 300 ohm flat twin feeder, but plastic-covered lighting flex will do instead. The feeder is connected to the dipole (A, A1) terminals at the receiver, or to the Aerial and Earth sockets if there is no dipole input. The feeder goes direct to the receiver and **NOT** via an aerial tuning unit (a.t.u.).

A loop is easy to use. Tune the receiver to the wanted station. Peak it up with the loop tuning control. Rotate the loop until you get the best results. A loop can be used to reduce static (atmospherics) if it is coming from a single direction e.g. from the south during the summer. Rotate the loop until the static is reduced or it disappears. Similarly with sideband splatter. Peak the loop onto the desired station and rotate the loop until the splatter is reduced. Overloading in the early stages of a receiver is often prevented when a loop is used, giving rise to the unlikely but accurate claim that a loop will sometimes improve audio quality.

Problems with Loops

A number of *PW* readers have highlighted problems encountered while building or using a loop. The most usual is that the loop will not tune across the entire band. For example, it may only cover 540kHz to 1450kHz. If so, then you will have to reduce the number of turns, so remove one complete turn. If you remove only part of a turn you will affect the null. The loop, which now has six turns, may cover 600kHz to 1650kHz. You need more capacitance. Try a 220pF fixed capacitor in parallel with the tuning capacitor, but you will have to fit a switch and cover the band in two steps Fig. 4. The number of turns affects the h.f. end of the range. If the loop tunes too high then more turns are needed. If it does not tune high enough in frequency then fewer turns are needed. The capacitance affects the l.f. end. Too low a frequency, too much capacitance. Not low enough, too little. Adjust the h.f. end first and then the l.f. end.

It is not always possible to obtain a 500pF variable capacitor so use the nearest value you can get hold of. A twin-gang 330pF (per section) with the two sections in parallel i.e. both sets of moving vanes joined together and also the two sets of fixed joined to each other, gives a total of 660pF which should cover the band easily. Similarly, a 330pF variable with a 220pF fixed in parallel via a switch, will cover the band in two steps.

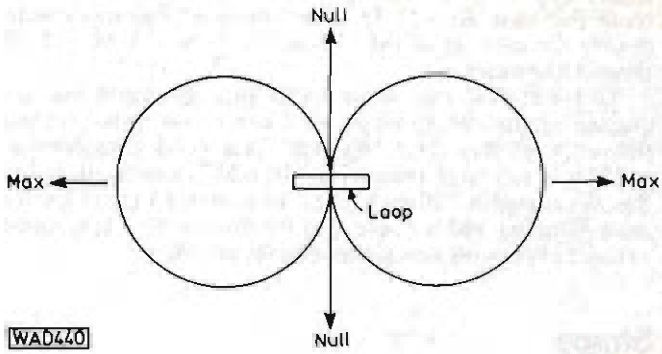


Fig. 3: The "figure-of-eight" polar response pattern of a loop aerial

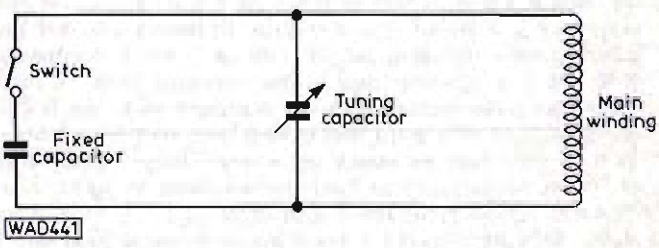


Fig. 4: Adding a switchable fixed capacitor allows a wider band to be covered in two ranges

What Type of Wire?

The type of wire for the windings is determined mainly by its mechanical properties. If the wire is too thin then it will break easily. If it is stranded then it may not be rigid enough.Too thick and a lot of force is needed to tension it. If it is made of steel it will be too springy (I have tried it with plastic-covered garden wire). Use the wire specified if you can get it. If not, use what is available.

Feeder

Some DXers use coaxial cable to join the loop to the receiver, which is a pity. You do not want the feeder to act as an aerial and pick up the station that is being nulled out by the loop. With balanced feeder the signal picked up by each of the two wires will be equal in value and will pass through the receiver in opposite directions (from A to A1 and from A1 to A). Since they are equal they will cancel out and the nett pick-up will be zero. When using coaxial cable, which is unbalanced, the screen will pick up more than the inner wire because the latter is screened. This may not matter too much if the receiver does not have a balanced input, but where dipole terminals are available, use balanced feeder.

Size

One of the most frequent questions is: "Can I use a different size loop?"

Yes you can. The pick-up of a loop depends on two factors: the number of turns and the area enclosed by them. As the turns are in series, the voltage developed across each will add up, so clearly the more turns the greater the pick up. You can compare two loops by using the formula At (A times t). The "40 inch" loop with 7 turns gives A = 1·04m² and t = 7 so At = 7·28. A "20 inch" loop with 13 turns gives A = 0·26m² and t = 13 so in this case At = 3·38. The "40 inch" has more than double the pick-up of the "20 inch": 7·28 ÷ 3·38 = 2·15 times, to be exact.

You will find that large loops pick up more but are clumsy to use. Small loops are more convenient but they deliver a lot less. The "40 inch" is a good compromise, but if it is too large then try a "20 inch". Reader Bob Bell has developed a "20 inch" box loop with 13 turns for the main winding and a single turn for the coupler. It is tuned in two ranges with a total capacitance of 750pF.

Shape

Any shape that is symmetrical will do—round, rectangular, diamond or even triangular. A triangle with a short base and a high apex is used by some DXers in the United States, where it is known as the Wedge or Delta loop. The diamond is used by a few enthusiasts and where the main winding has all the turns in the same plane it is known as the Spiral Loop, which is the type I use (Fig. 5). Each turn is of a different size of course. In theory you will get a better null if the turns are all in the same plane, compared with the box winding used in the standard loop. In fact, the effect is very small with the standard loop, but it can be significant with loops that have a large number of turns.

It is very easy to knock up a spiral loop. Two pieces of wood, some tacks to hold the windings in place, 31m of wire, a tuning capacitor and there you are. It is a lot more difficult to make a good job of a spiral loop and I would hesitate before making another one.

Long Wave Loop

You can get a m.w. loop to work on the long waves by inserting a loading inductor in series with the main winding. I use a Repanco High Q Choke type CH1 which has an inductance of 2·5mH but any value between 2·5mH and 5mH will do. Unsolder one of the loop wires from the tuning capacitor and join it to one side of the inductor. Join the other side of the inductor to the vacated tag on the tuning capacitor.

Alternatively, you can extend the range of a loop by adding parallel fixed capacitance across the tuning capacitor, but the values required are so large (2200pF to reach 300kHz and 7000pF for 150kHz) that the tuning capacitor no longer functions. This will not matter, though, if you only want to listen to a single station, and this method is employed by Arthur Tate in the Shetlands, who endeavours to get better reception on 200kHz this way.

If you want to wind a special long wave loop then approx. 3½ times the number of turns (25–28 for a "40 inch") are needed, but this loop will pick up 3½ times the signal of a m.w. loop with loading coil, which may justify the effort in building it.

Tilting

This is not a medieval past-time! It is a method of increasing the depth of the null when the wavefront is twisted or rotated. It is popular with DXers in the United States, who have a lot of locally-produced QRM to deal with. When a station is being nulled out, the loop will be broadside-on to the incoming signal. If you pick up the loop and tilt it towards, or away from the station, at the same time holding the null position, you may get a deeper

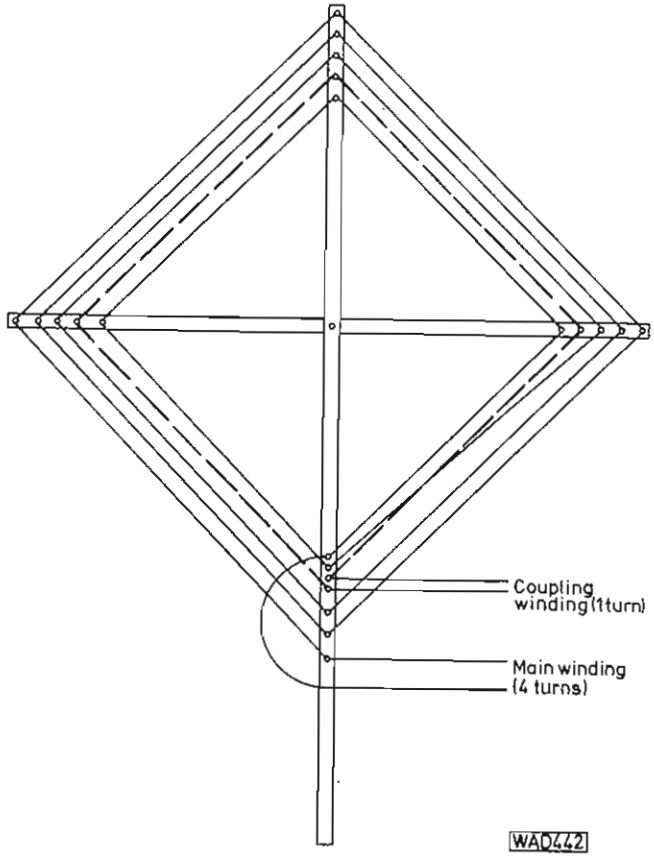


Fig. 5: Arrangement of a spiral loop

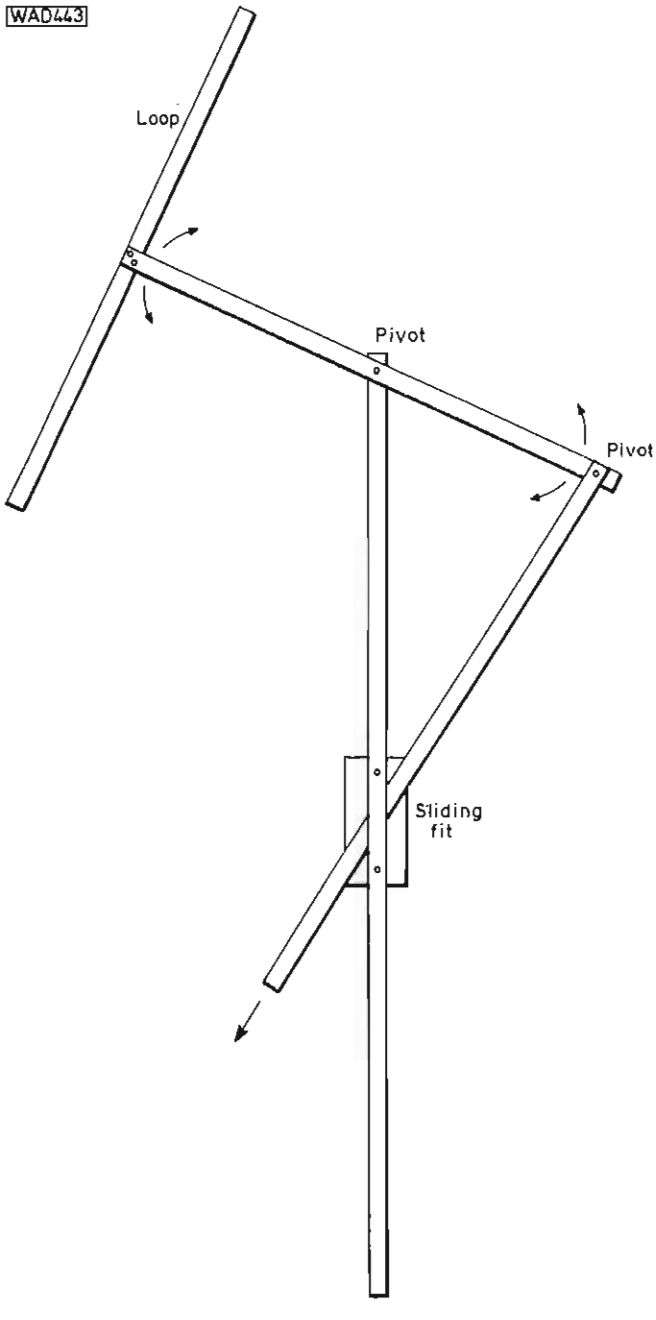


Fig. 6: Details of a simple wooden mounting which allows a loop to be tilted from the vertical

null. You can modify a normal loop so that there is no need to lift it off the floor. One method of doing this is shown in Fig. 6.

Coupling Winding

The single turn on the standard "40 inch" loop is called the coupling winding and its existence has puzzled quite a few readers. This winding is not joined in any way to the main winding. It is quite separate since the transfer of signal from the main winding is by induction. Why use a coupling winding? If you joined the main winding direct to the receiver then the loop would be damped and detuned by it. The two are in effect a 7 : 1 step down transformer which provides a better match.

Varicap Loop Tuning

"Have you tried varicap loop tuning?" asks **P. W. Simmonds** (Isle of Wight), who goes on to describe a tuning device he constructed using a MVAM115 varicap (available from Ambit International), two 10nF capacitors, one 100kΩ resistor and a 100kΩ potentiometer which, he claims, cost less than a variable capacitor. The diagram (Fig. 7) shows the set-up. The negative side of the power supply used was earthed, but this is not essential.

It never occurred to me to try varicap tuning, as a stabilised power supply is required. However, Mr Simmonds says that he was able to mount the 100kΩ pot, which is the tuning control, close to the receiver, which also supplied the 12 volts. This arrangement was a lot more convenient to use than operating a tuning capacitor fixed to the loop.

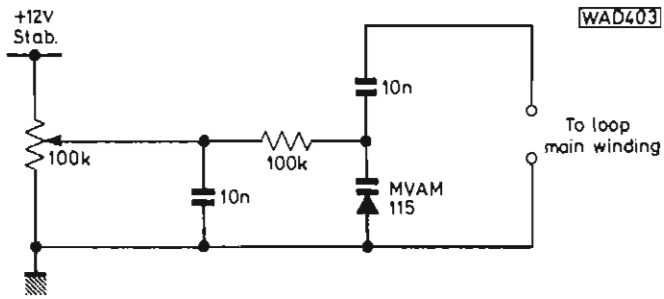


Fig. 7: A medium-wave loop tuning circuit using a varicap diode

Portable Receivers

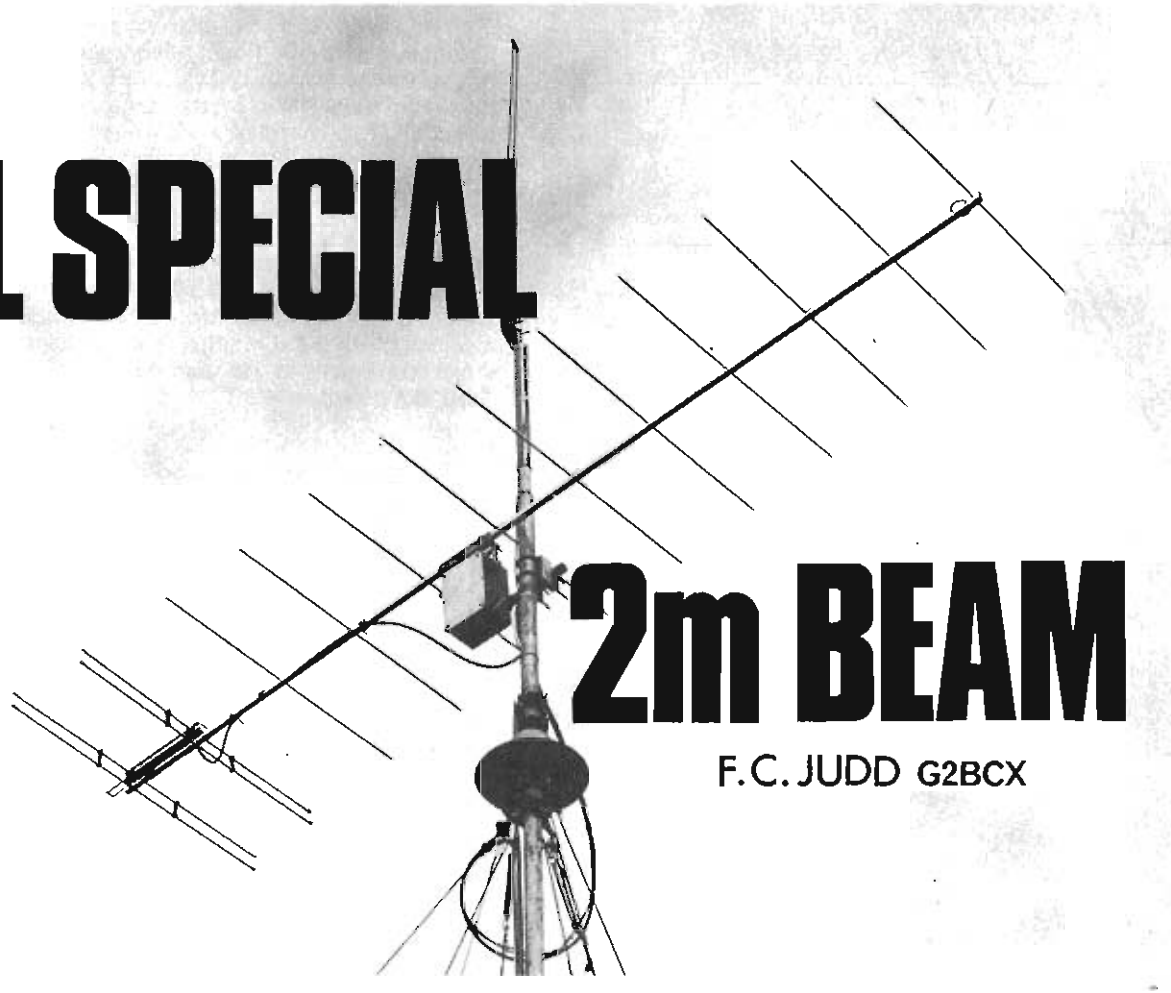
Many DXers try to use a loop with a portable, forgetting that the receiver already has an aerial of its own. No null, is the result. If the loop nulls out a station then that station is still picked up by the internal aerial. You could of course rotate the portable as well as the loop and null out the QRM with both aerials, but in practice this would be very difficult to do. The solution of course, is to mount the receiver on a shelf near the centre of the loop so that the two nulls co-incide and loop and receiver can be rotated together. This arrangement really does work.

There is no need to connect the loop to the receiver, as inductive coupling will take place between loop and internal ferrite rod aerial. In fact if you build a loop solely for use with a portable you need not bother with a coupling winding at all. It is easy to check if the receiver has an internal aerial. If it can pick up stations on the medium waves without an external aerial, then obviously there must be an internal one.

The better type of portable receiver performs really well on the short waves but the pick up via the internal aerial is not great enough for serious DXing on the medium waves. This method of using a loop with a portable is really the only way that such a receiver will "deliver the goods" on the medium waves. DXers seriously interested in the medium waves should turn away from portables, even those with the title "communications" and look for a receiver such as the DX160, SRX-30, FRG-7, Trio 9R59-D/E, CR100 or AR88 which really are communications receivers. Be careful with the DX160. Some versions have a ferrite rod aerial attached externally to the rear which must be disconnected before a m.w. loop can be used.●

ZL SPECIAL 2m BEAM

F.C. JUDD G2BCX



In my article "Aerial Performance Test Set", (*Practical Wireless, January 1978*) readers may have noticed the photograph of a 12-element beam aerial. This is one of the "ZL" series, developed from the ZL Special, details of which were published in *Practical Wireless*, May 1977. At the time, the principle of employing two driven elements to produce 'end-fire' arrays was examined. The ZL Special two-element system is in fact an end-fire array but with a difference. The element lengths are cut to produce a reflector/director action which gives increased forward gain over that normally obtained with two half-wave elements spaced $\frac{1}{8}\lambda$ and driven 135° out of phase.

The ZL Special, apart from being a small beam aerial in its own right, is also a very useful primary driving system for relatively compact multi-element beams of higher gain. In this respect, the reader may find the article "Three and Five-Element Compact Beam Aerials for 2 Metres" (*Practical Wireless*, May 1977) of interest. The same arrangement can be used for ZL beams of up to five directors—i.e., six or seven elements total.

Beyond this however, if the gain is to be increased by additional directors and the size contained, the construction of the ZL Special as described in the above article must be modified.

The 12-element ZL beam to be described was developed nearly three years ago and up to the present time has been in use in two quite different locations. One of these was my former address in London and the other my present home in the lovely countryside of Norfolk. It has been the means of establishing over 600 direct contacts with more than 10 countries outside the UK on 2 metres f.m. Operation into a number of continental repeaters, as well as distant UK repeaters, has been achieved with only slight tropospheric lift.

The basic ZL Special has a forward gain of about 6dB over a dipole, which is much higher than can be obtained with a single driven element and reflector, the basis of the well-known Yagi. A ZL beam with directors does not require a reflector, as there is nothing from the rear to reflect. With the modified primary driving array and 10 directors as shown in Fig. 2 a forward measured gain of 13·5dB can be obtained with a beamwidth at the 3dB down points of approximately 36°. The theoretical gain was 14dB but calculated parameters are rarely, if ever, realised. For the sake of comparison with the dipole and other ZL beams however, the radiation pattern of 12-element version is shown in Fig. 1; the field intensities are relative.

At this point it should be realised that if a high-gain beam is used the increase in effective radiated power (e.r.p.) over a simple dipole is considerable. For example if 10 watts of actual radiated power is applied to a beam aerial having a gain of 13dB, it will produce an e.r.p. of close to 200 watts (assuming no losses), 13dB being a power ratio of approximately 20:1.

Before the constructor begins to build this aerial

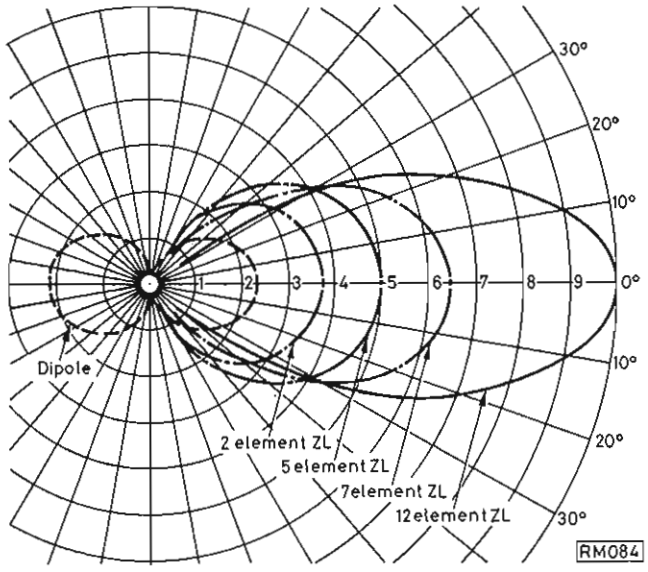


Fig. 1: Field intensity patterns of the 12-element ZL Beam and other ZL Series for comparison. Intensity levels are all relative to each other and a dipole

it should be stressed that only the materials specified must be used. As with most projects of this nature if the text is not followed closely, it is unreasonable to expect the results to function properly. The dimensions are fairly critical, and a tolerance of about one per cent should be aimed for in the longer lengths. In other words, about 2·5mm in 254mm. For shorter dimensions, 1mm is adequate.

It seems a gremlin was at work when copy was written for the announcement about this article on page 43 of our October issue. We apologise for the wrong information given there.

Construction

From Fig. 2 it can be seen that the overall length is some 3·2 metres but if the elements are made as described from 6·3mm diameter aluminium rod or tube, a boom of 20mm square aluminium is adequate for the purpose. The prototype built exactly as described in this article has withstood gale force winds and gusts approaching 90m.p.h., suffering nothing more than one broken director.

The diagrams should be fairly self-explanatory. The layout of the two driven elements, the 300Ω ribbon phasing line, the rear tuning stub and the small coaxial capacitor across the feed point are shown in Fig. 3.

Note that the ribbon feeder forming the phasing line is somewhat longer than the actual spacing between elements and this will lie slack within the protection box. The box may be of pvc or built from hardwood. In the latter case it is advisable to fit sleeves of a good insulating material over the elements and the rear stub where they enter the box.

The small rear stub is made from 6·3mm diameter aluminium rod or tube. The lower parts of the elements run underneath the boom. They must not come into contact with it but extra support could be given with small spacers of Perspex or pvc located between the centres of the elements and the boom.

The small capacitor is formed from a short piece of 50Ω coaxial cable, trimmed at one end by about 20mm for connection to the feed point and with about 12mm of screening braid removed at the far end to prevent short-circuit or r.f. flashover.

The boom is 3·234m long and 20mm square. All the directors are secured to the boom at their exact centre points. For this purpose small clips could be used or holes drilled through the boom to take the 6·3mm diameter rods, which can ultimately be secured by bolts or self tapping screws. Whichever method is finally decided upon it will be necessary to establish that the electrical contact is good.

When the aerial is finally tested, the slots where the elements enter the protection box can be filled with Plastic Padding or similar to prevent the ingress of water. After the lid has been fitted the box should be painted or varnished.

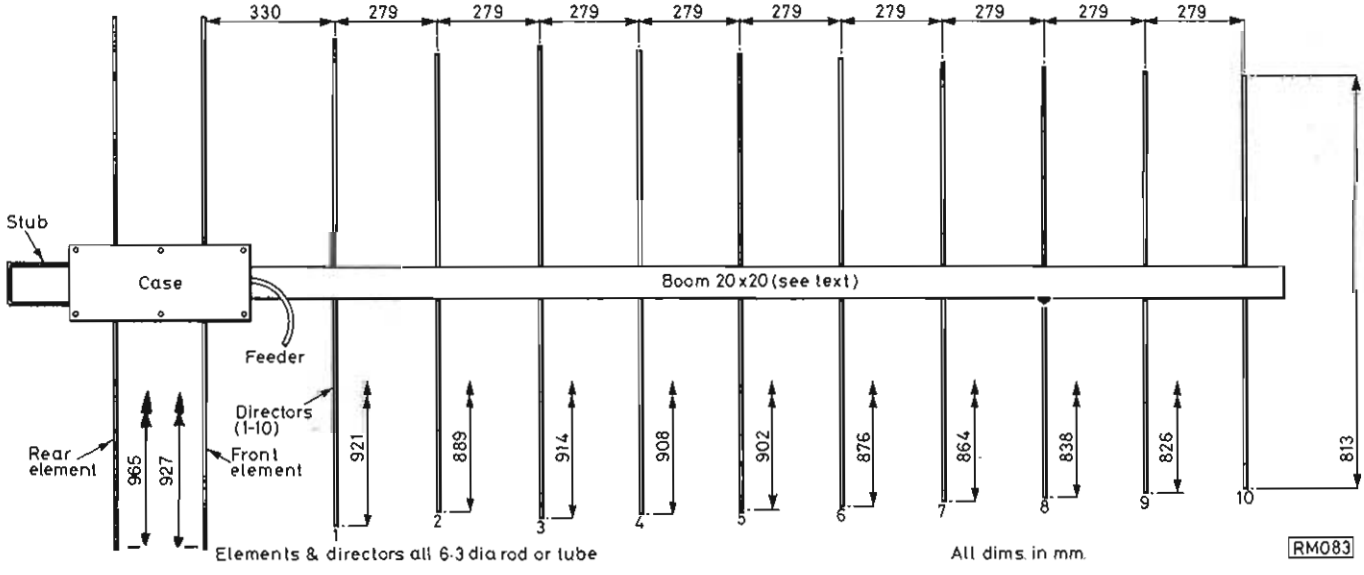


Fig. 2: Details of element and director lengths etc. These are critical and should not be altered in any way

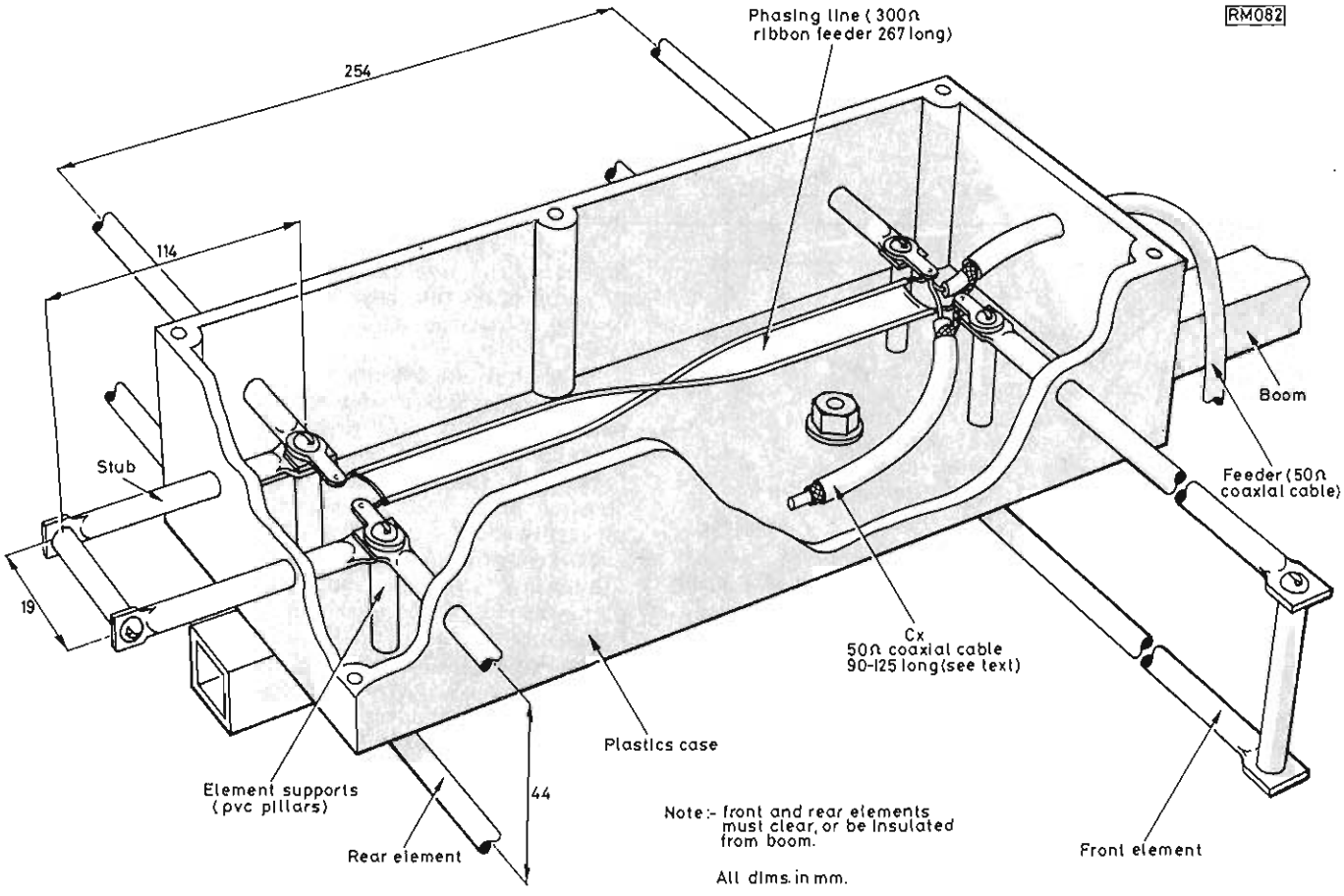


Fig. 3: Details of the driven element assembly

Checking and Operation

This aerial will only operate with 50Ω coaxial cable which should be of good quality. Type UR67 is recommended for long runs but UR43 may be used for lengths of up to 10 to 12 metres without too much loss. It is advisable not to use old cable (eg cable which has been in use outside) as losses develop, usually due to moisture absorption and this will degrade the performance of the aerial.

Before fixing the lid to the protection box make sure all connections are secure. Large soldering tags, say 2BA, clamped under the element ends, are best for good soldered contact of the main coaxial cable, the phasing line and the coaxial capacitor. For testing, the full length of 50Ω cable should be connected. Set the aerial up in the garden, balanced on a pair of steps so that it is about 1 to 1½m above ground. If a v.s.w.r. meter (or power meter) is available and/or fitted to the transmitter, check at mid band (145MHz), that the v.s.w.r. does not exceed 1·5:1. If it is higher then a problem, perhaps with connections, is indicated. If the v.s.w.r. is below 1·5:1 then leave well alone! However, adjustment can be made to the coaxial capacitor length for minimum v.s.w.r. It may mean trying two or three pieces of say 90mm, 100mm and 125mm but the trouble will be worthwhile. If you have available a 6 watt fluorescent tube it should light brightly when touching the ends of the driven elements and most of the directors when 10 watts or more of r.f. is present.

If the v.s.w.r. is plotted across the band the curve should approximate that shown as (b) in Fig. 4 provided the feeder cable is not too long. For runs of 20m or more the curve will tend to flatten out as (c).

For comparison, an average v.s.w.r. curve for a long Yagi is shown in (a) and the increased rise at each end is due to the fact that such aerials are sharply resonant. The ZL series are broad-band hence the flatter v.s.w.r. curve. The beam width at 3dB is about 36°, as in the polar patterns of Fig. 5 which were taken from the prototype. The solid line is for horizontal polarization and the broken line for vertical, but note that the spurious lobes in the vertical pattern, due to reflection from nearby conductors,

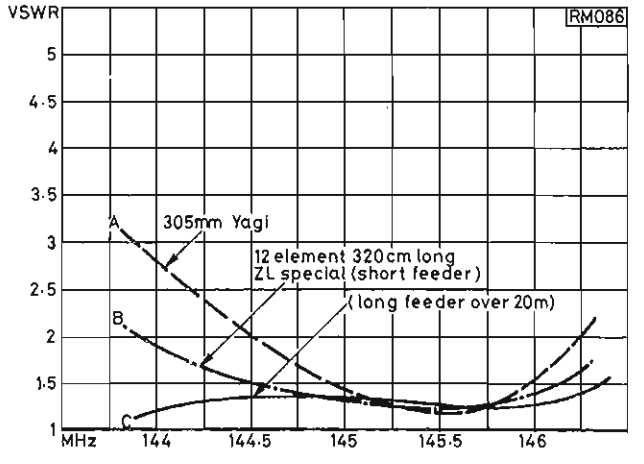


Fig. 4: VSWR plots, ZL Beam by comparison with long Yagi

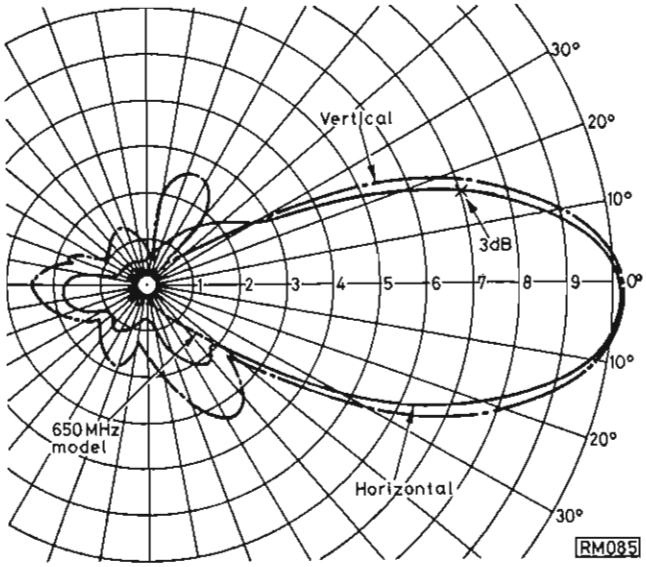
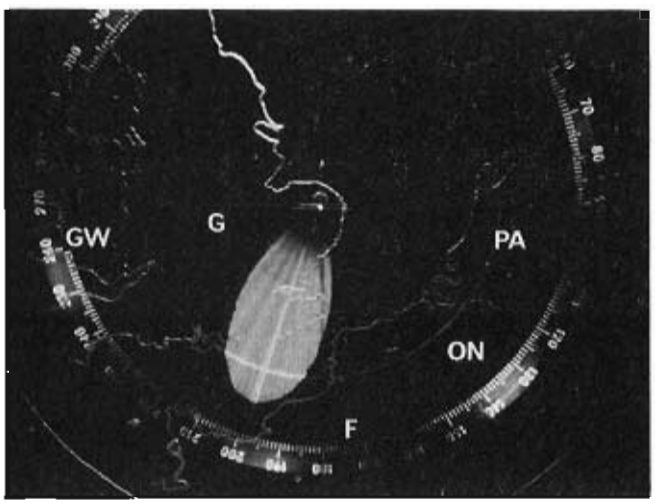


Fig. 5: Measured vertical and horizontal radiation patterns of the 12-element ZL Beam, taken at 145MHz

are fairly typical when a high gain aerial of this nature is used in a built-up area.

The polar pattern from a 650MHz model of the aerial compared almost exactly with the 2 metre version and this is shown in the photo taken from a polar scan display unit which I have recently built to operate in conjunction with a model antenna performance measuring system.



Installation

A beam aerial of this nature obviously needs a 360° rotator but being quite light in weight does not need a high powered device. In the photograph of the aerial, can be seen a small oblong box (at the centre) and this is a vertical to horizontal rotator which allows the aerial to be operated vertically or horizontally, or at any intermediate angle. Such a rotator is not difficult to make and really all that is required is a reversible d.c. motor, some Meccano or similar gear wheels and a little ingenuity to arrange an auto-stop (micro-switches) and a reversing and stop control box. ●

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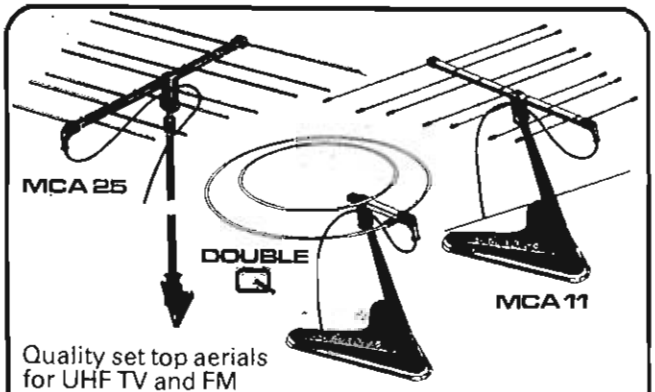

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SPECIAL PRODUCT REPORT

DATONG ELECTRONICS LIMITED

ACTIVE ANTENNA MODEL AD170

For those enthusiasts who enjoy the l.f. and h.f. bands an efficient antenna is a fundamental necessity and whilst many may dream about three-element beams on 120ft. towers, few will be fortunate enough to be able to obtain one. Some, such as those living in flats, may well be denied any outside wires at all and this group in particular should reap the greatest benefit from an active antenna.

The Datong AD170 Active Antenna is a matched set of modules which, when assembled, exhibits some of the characteristics of a full size half-wave dipole. The kit consists of a short wire dipole, each leg being connected to a high-impedance differential input amplifier whose output is arranged to match a low impedance feeder which carries the signals to the receiver. Some signal amplification is also achieved within this module.

A second "interface" unit mixes d.c. power with the r.f. output signal, which is fed via coaxial cable to the antenna module. Its power input is filtered to avoid interference pick-up and is also protected against a polarity reversal.

The Datong units are designed for indoor use and may be installed almost anywhere, an ideal position being the loft or similar high siting. Try to avoid places likely to be influenced by electrical noises, such as may be experienced from fluorescent lights. Remember also that water tanks, overflow pipes and so on will also affect the performance of any antenna.

The two wires from the head amplifier are stretched out and the ends attached to convenient fixing points (rafters, etc.) by non-conductive material—string, for example. For this purpose, two loops are provided. Optimum orientation of the dipole will depend on many factors, such as distance from the transmitter, mode of propagation, transmitter polarisation, time of day and operation frequency, so some experimentation is necessary. Vertical or near-vertical mounting is recommended for frequencies above 10MHz. This will give omnidirectional reception of ground waves (e.g. from l.f. stations) and of low-angle sky waves from DX stations. Reception of high-angle sky waves from medium distance stations will be relatively poor, however.

Horizontal mounting gives almost omni-directional reception of high-angle sky waves and directional reception of low-angle sky waves. In the latter case, maximum response will be obtained when the line of the dipole wires is

★ specification

Frequency range: 60kHz–70MHz
Output impedance: 50Ω
Differential voltage gain of amplifier: Unity
Recommended dipole length: 3m overall
Third order intermodulation products: typically −90dB relative to two output signals of 100mV e.m.f. (Equivalent to 100mV p.d. at the differential inputs)
Second order intermodulation products: typically −80dB relative to two output signals of 50mV e.m.f. (Equivalent to 50mV p.d. at the differential inputs)
Current consumption: 80mA
Supply voltage: 12V d.c. nominal

The Datong AD170 is supplied as a package containing the active aerial, the interface unit, 2 × 1·5m antenna wires, 1 × 4m jumper cable and a 3·5mm jack plug. The mains power unit shown in the photograph is an optional extra.

Price: Antenna £37.95 incl. VAT
Power Supply £6.90 incl. VAT
Both units (inclusive price) £42.55 incl. VAT

Datong Electronics Ltd, Spence Mills, Mill Lane, Bramley, Leeds LS13 3HE Tel: 0532-552461

perpendicular to the line between antenna and transmitter. Null responses occur in directions along the line of the wires and can be used to reduce local interference.

The AD170 has a frequency range of 60kHz to 70MHz. On "medium" and "long" waves there are many strong stations which call for a very good intermodulation performance from a unit such as this. At −80dB on second-order products and −90dB on third-order products the Datong antenna fulfils this requirement admirably.

The interface unit previously referred to contains a switchable amplifier of 12dB gain which will help compensate for the poorer h.f. performance of some older receivers, but is not essential if the unit is to be used with more modern equipment. It is, however, very convenient to have a couple of S-points extra gain available when required to winkle out that elusive DX station.

On test, the AD170 gave very impressive results. It should be fully-understood, however, that the level of signal at the receiver will only compare with that from a full-size dipole at frequencies of about 16MHz, appearing to be about one S-point better at 30MHz.

Below 16MHz the "gain" relative to a full-size resonant half-wave dipole falls at approximately 6dB per octave and at 2MHz will be three S-points down on a 75 metre passive dipole. However, this may not be as dramatic as may first appear, because at 2MHz the level of signal received on a full-sized dipole is considerable, as is the noise level. The active antenna worked quite satisfactorily at these frequencies and its all-important signal-to-noise ratio was at worst equal to and in many cases better than the full-size dipole against which comparisons were made.

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VHF DF LOOP AERIAL

F. C. JUDD G2BCX

An interesting exercise, not only in radio direction finding but in map reading as well, is provided by v.h.f. DF hunts, frequently run by radio clubs. When a *horizontally* polarised aerial is used by the hidden transmitter, then a small beam aerial or dipole could be used to obtain direction, although with a beam one has to estimate the maximum received signal, which is not defined enough for obtaining accurate bearings. Providing it is properly balanced, a dipole is better, as the nulls in the polar pattern (minimum signals) are much more defined. If the hidden transmitter is using a *vertically* polarised aerial, then a dipole is of no use, as it becomes omnidirectional when used vertically. A small conventional beam aerial presents the same problem, in that the maximum signal indication is not defined well enough to obtain accurate bearings. The 2-element ZL Special (*PW*, May '77) is an exception however, and is very useful for DF work as it has one fairly sharp null. Its polar pattern is cardioid when the aerial is operated vertically, but more of this later.

The loop aerial described in this article is for use when signals are from a *vertically* polarised source. It consists of a split loop, one half-wavelength in circumference, tuned and balanced to operate with 50 ohm coaxial cable as shown in Fig. 1(a). The current and voltage distribution, together with the direction of the current in each half-loop (arrows) are shown in Fig. 1(b). Since the currents in each half are in phase opposition, the polar pattern is a figure-of-eight, like that of a horizontal dipole, with two maxima and two minima as in Fig. 1(c).

This loop will also operate very efficiently as a transmitting aerial with a v.s.w.r. close to 1 : 1 when properly tuned. This means that stations, mobile or handheld, taking part in the DF hunt can communicate with each other to pass bearings and map readings, etc., without having to change aerials. It is appreciated that this loop system does not provide a means of sensing, i.e. of determining which minimum is giving true direction, but this is not greatly important when two or more stations at reasonable distances apart are working as a team. Information on direction finding is given later.

Making the Loop Aerial

General construction details for the loop are given in Fig. 2. The loop itself is made from 4·7mm ($\frac{3}{16}$ in) diameter aluminium rod although 6·3mm ($\frac{1}{4}$in) may be used. Bending the rod to form the two half-circles is not difficult if done gradually and with aid of gentle heating from a small blow-lamp. The bottom ends are flattened by hammering on a hard surface, after which they can be filed smooth and drilled 4BA clearance as shown.

The lower mounting block, and the top block that supports the upper ends and keeps them separated, must be made from Perspex or similar good-quality insulating material. The upper ends are at high r.f. potential. The box for mounting the loop on and housing the two 30pF trimmers may be a plastics electrical junction box, or similar, with removable lid and of dimensions approximately as shown. The handle can be a short length of 25mm dowel or broomstick, secured to the underside of the box with a wooden collar, by gluing and screwing.

The diagram Fig. 3 shows how provision is made for a compass platform and a sighting bar. Note also the hole each side of the box allowing access to the 30pF trimmers after the aerial is assembled and ready for tuning. Connection to the loop from a length of 50 ohm coaxial cable is made via the S0239 socket at the base of the box.

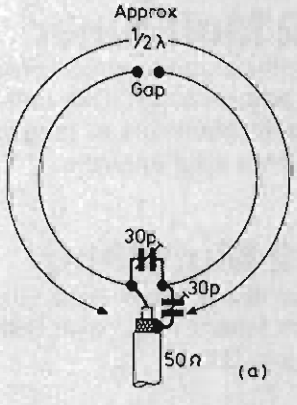

Fig. 1(a): Configuration of the ½λ loop

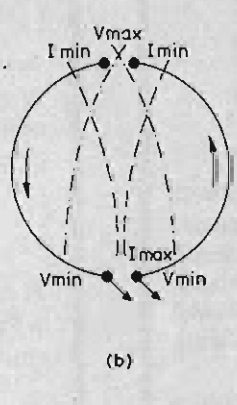

Fig. 1(b): Current and voltage distribution

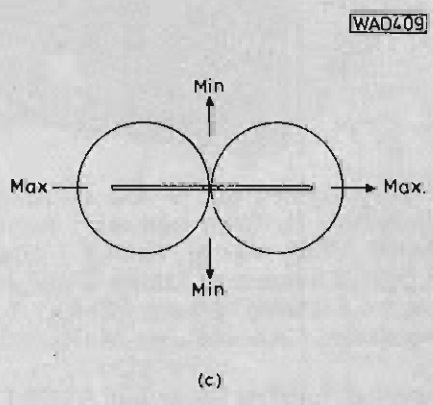

Fig. 1(c): Polar pattern of the loop

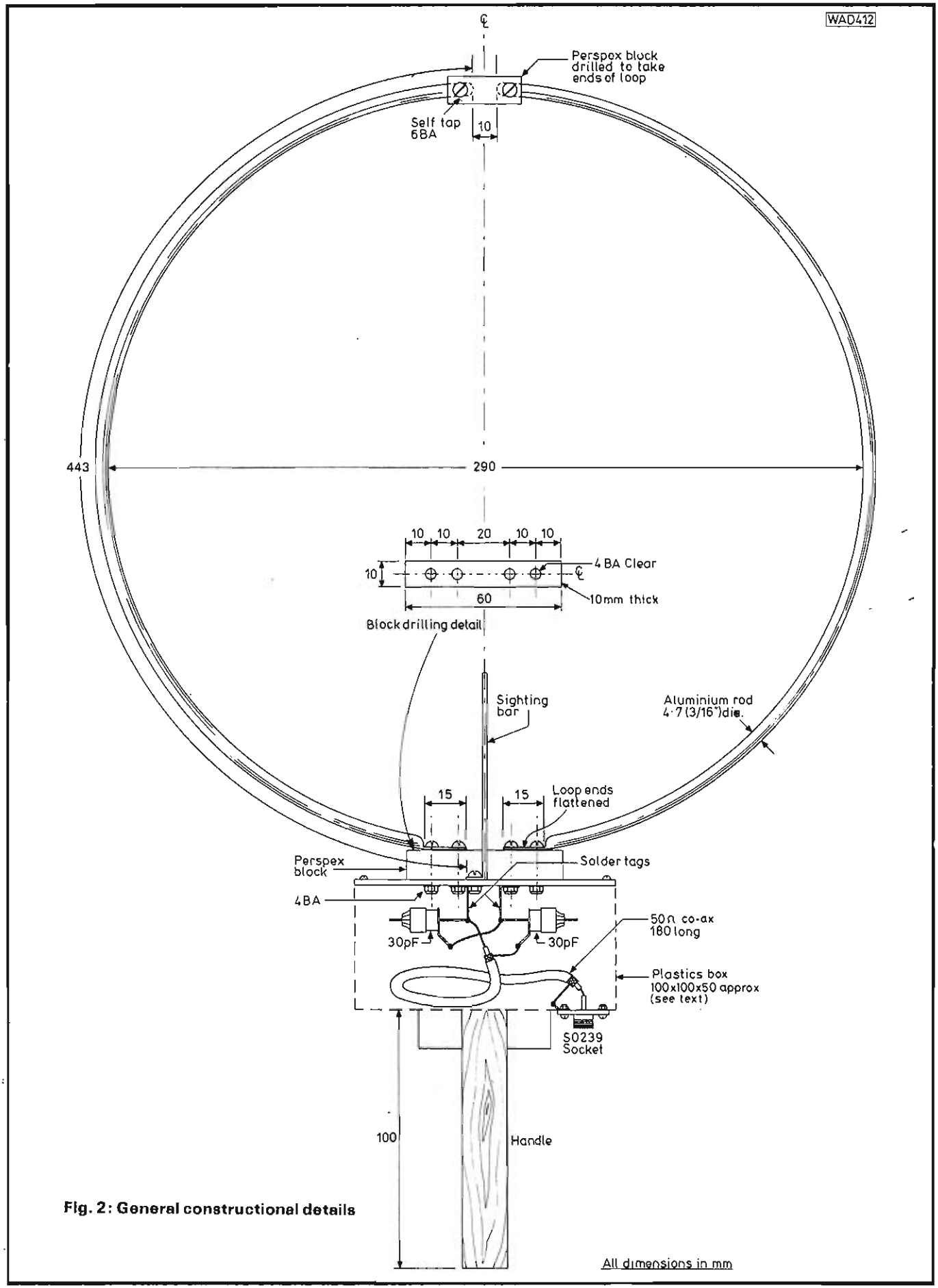

Fig. 2: General constructional details

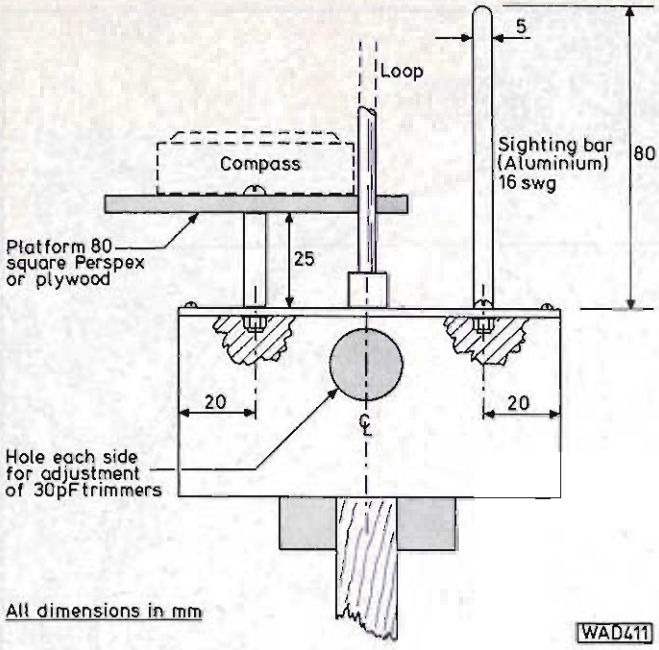

Fig. 3: Arrangement for a compass platform

Tuning and Checking the Loop

The length of the external coaxial cable will depend on how the loop will be used. For example, when connected to a mobile rig, one will need to use the loop a metre or more from the car to avoid reflection from the car body, so that about 3 metres of cable should be used. Handheld transceiver operators will need only about 1 metre. The length is otherwise not critical and may be chosen entirely to suit convenience.

With the loop aerial connected to the transmitter/receiver and with the length of coaxial cable decided upon, all that is necessary is to adjust the two trimmers for maximum power (on transmit) into the aerial, or better still, minimum v.s.w.r. Do this at midband (145MHz) and tuning will hold good to the outer limits of the band. If a receiver only is to be used, then adjust the trimmers until a received signal is at maximum. Remember the loop has two nulls and two maxima, so for a transmitting test with another station the loop must be end-on to that station for maximum signal. Checks for the two nulls (minimum signal) should be made out of doors and well clear of other 2m aerials, and indeed any other conducting elements likely to cause reflection and give rise to false nulls. Each null should be sharp and reduee a received signal down to noise level or even completely out. Cheek also that the nulls are 180° apart.

A small hand type compass can now be fitted to the compass platform. It need not be permanently fixed, but instead seeured with strong elastic bands and aligned so that 0/360° points to one side of the loop, i.e. in the direction of the null in line with the sighting bar.

Direction Finding

The polar pattern shown in Fig. 4, taken with the writer's Polar Pattern Indicator aerial performance display, is from the prototype loop. It elearly shows a virtually perfect figure-of-eight shape with two well-defined nulls at 305° and 125° respectively and therefore 180° apart. The other pattern (Fig. 5) is an almost perfect cardioid from a two-element ZL Special. In team operation in a DF hunt this can be used for "sense" of direction. Once this has been obtained, the remainder of the team can be notified that the hidden transmitter is to the North or the East (or whatever) general direction from them.

For those new to radio direction finding the following notes may be found useful. Ordnance Survey maps 1 : 50 000 series with 1 kilometre squares are ideal for DF work. Indeed, they arc essential if accurate results are to be obtained, especially when the start of operations may be several miles from the transmitter to be located. A team of three is ideal if location is to be found quickly, although two operators could work together fairly efficiently. A lone operator would need to move about a lot more in order to get the necessary cross bearings.

The illustration (Fig. 6) is based on the 1km squares of a 1 : 50 000 Ordnance Survey map, and here the hidden transmitter is on a reference of approx 67 Easting and 92 Northing (note that on a full-scale map, the Eastings and Northings are each given in three figures, making six

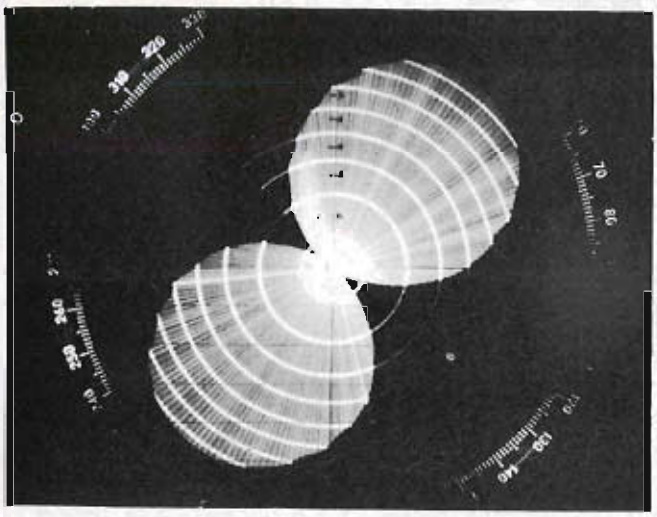

Fig. 4: Actual polar pattern of prototype loop aerial

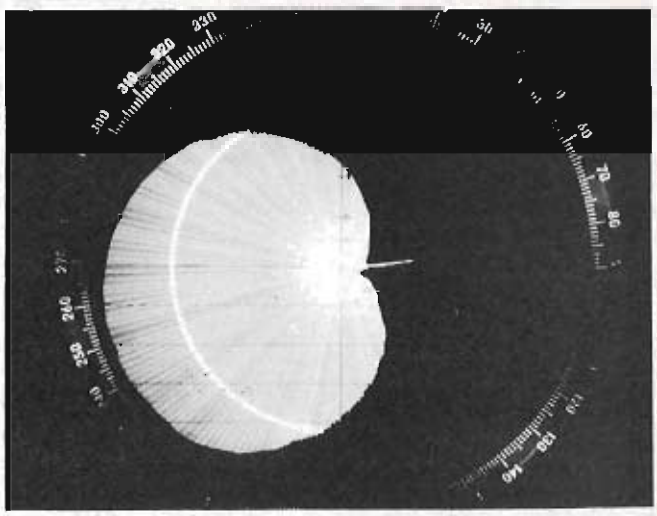

Fig. 5: Cardioid pattern of the 2-element ZL Special

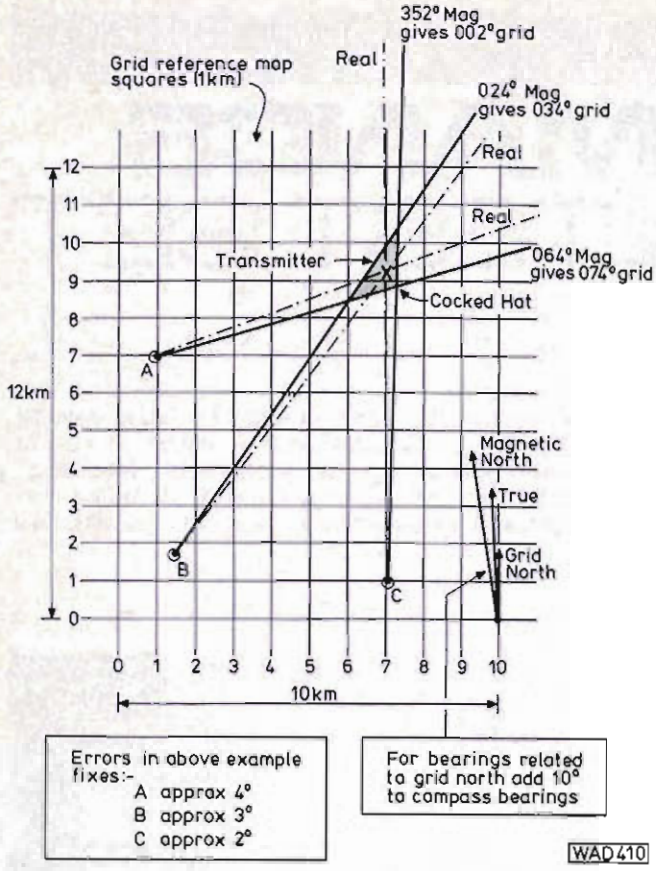

Fig. 6: Example of obtaining a fix on a hidden transmitter from three positions. Errors shown are about average in practice, but do produce the "cocked hat" area enclosing the true position

figures for the full grid reference). The bearings taken by DF stations A, B and C are shown by the solid lines and are about average as far as error is concerned. They form a triangle of "cocked hat", around the true position of the transmitter. Remember that we have started from several miles away, but at this stage have located the transmitter to within about a square kilometre. The next step is for each member of the team to move in closer, in this case A goes to point 96, B to 86 and C to 88. Even with similar errors in bearing, e.g., between 2 and 4 degrees, the now much shorter range should establish a location of the transmitter to within an area of about 0·1km or a little over 100 yards square. The procedure can be repeated and again, with average errors, location to within 0·01km or about 10 yards square should be possible.

Remember, that an Ordnance Survey map grid North is slightly different from true North, and magnetic (compass) North is different from true. The total amount to be added to a magnetic bearing for the grid map is about 10°. If, for example, your magnetic bearing is 024° then using the vertical grid lines of the map as 0/360° (North) the bearing to be plotted on the map will be 034°.

Ascertaining the null is usually best done by listening, preferably on headphones, and accuracy in obtaining the minimum stems largely from practice in aurally estimating this, although a signal level meter is helpful of course. Remember that nulls can sometimes be confused by the arrival of signals from other than the direct path, due to reflection, so if a null appears to be confused or not well defined, try moving to another position. ●

KINDLY NOTE!

VHF DF Loop Aerial

A few readers have queried my statement in this article which said: "For bearings related to grid North add 10° to compass bearings". (Fig. 6.) This should have said *subtract* 10° from compass bearings, an error for which I apologise, having fallen into a trap which I unwittingly set up in the first place. How this occurred is not important but an explanation about the reason for this 10° difference may be of help.

A radio direction finding loop indicates a *true* direction relative to *true* North whereas a compass indicates a direction relative to *magnetic* North. The difference, including a further small variation for grid reference maps as explained in the article, is approximately 10° and this is accurate enough for practical purposes in radio direction finding. So, if we take grid *(true)* as 360° on a protractor aligned with the map grid lines then a compass bearing of an object lying in this direction would be 10° *magnetic*. Subtracting this therefore gives 0/360° grid *(true)*.

The text on page 52 (second column) said that the compass can be fitted and aligned so that the 0/360° mark points to one side of the loop, i.e., in line with the sighting bar which is at 90° to the loop itself or on axis with a null. This means that when looking through the loop, along the line of a null and with the compass reading 0/360° *magnetic*, then the loop is also in alignment with *magnetic* North.

Again, subtract 10° to obtain the grid *(true)* bearing of 350°. A further example: You have a null from a transmission which although unknown to you, happens to be in a grid *(true)* direction of say 40°. The compass will be reading 50°. Since you will have to get the grid *(true)* bearing from the compass anyway then subtract the requisite 10° to obtain 40°. Further apologies for not having explained this more fully in the article.

F.C. Judd G2BCX

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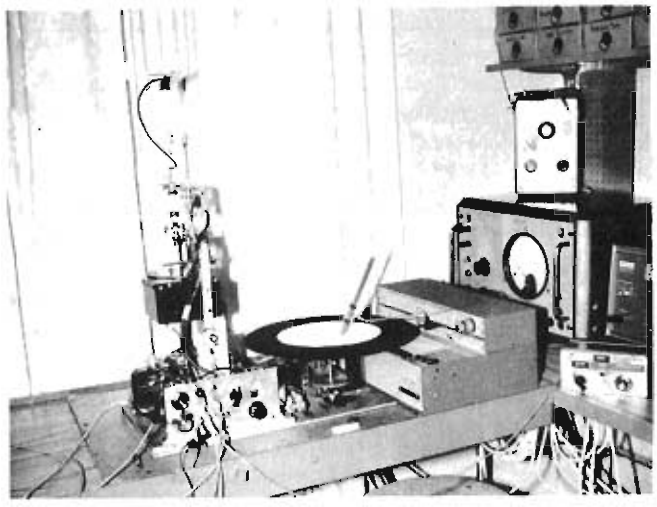
Transmitting and receiving aerial performance is difficult to measure with any degree of accuracy particularly when the operating frequency is low and the aerial is, of necessity, very large. At frequencies as high as 28MHz (10m band) one would find it physically impossible to plot the vertical angle radiation pattern, or indeed the plane polar pattern, with the aerial operating in either vertical or horizontal polarisation mode. At 145MHz (2m band) the problem is eased somewhat since the aerials are physically small but even then they need to be mounted very high in order to obtain true "free space" radiation patterns. Further, the transmitted signal source must be a large number of wavelengths away and/or the receiving point must be at a similar distance if the aerial being tested is radiating.

It is usual to test an aerial under receiving conditions; the final result is the same. The writer has in use a 60ft high mast that can be lowered to half way so that 2m aerials for testing can be mounted on a special rotator system that will turn the aerial through 360° as well as from horizontal to vertical mode. The system is remote controlled from the measuring instrument position and the distant transmitters normally used are GB3VHF for horizontally polarised signals and GB3PI, or local amateur stations for vertically polarised signals. Even so, the process of carrying out polar pattern and gain measurements is laborious to say the least, and indeed somewhat hazardous, especially when large beams (a recent one was a 12-element ZL Special) have to be hoisted to a small platform about 30ft above ground before being raised to full height for tests. On new designs there is the added problem of making modifications, so an aerial may have to be hauled up and down several times before the design can be approved.

The Theory of Similar Structures

It is well known that aerials scaled down in frequency behave in exactly the same way as they would at the original frequency. At one time the writer used a frequency of 10000MHz to operate a model aerial system capable of obtaining quite accurate polar patterns of both plane and vertical radiation fields. At such a high frequency however, impedance matching, with any degree of accuracy, becomes very difficult indeed.

The "theory of similar structures" is applied in many spheres of engineering. For example, for proving ship's hulls by using scaled-down models in wave tanks, models of aircraft in wind tunnels and models of bridge structures etc. It is readily adaptable to transmitting aerials and if we take a dipole for example, its familiar figure-of-eight radiation pattern is exactly the same whether the aerial is cut to operate on 2MHz or 200MHz, or any other frequency. This applies, of course, to aerials of all other configurations and to directivity, gain and polarisation as well.



The author's aerial measurement set-up, with aerial under test mounted on a turntable, plus a pen chart recorder.

Scaling down makes the aerials much smaller, easier to construct and handle, reduces the distance between the source of transmission and the aerial being tested, and brings the "free space" position much nearer the real earth. If the effect of earth is required as part of the measurement then a metal ground plane of several square wavelengths extent is no great problem. As mentioned however, if the scale frequency is too high matching the aerial to its feed point becomes a problem and to overcome this frequencies of between 600 and 1000MHz are commonly used.

Some years ago the writer used 800MHz for the original design of the "ZL Special" end-fire beam for operation on 14 and 28MHz and which was described in *PW* recently for 2m operation. At frequencies around those mentioned quite accurate matching is possible, materials for constructing the aerials can be scaled down, as can transmission lines, matching stubs and baluns etc. Even "miniature" co-axial cable, with little loss up to around 1000MHz, is readily available.

A Model Aerial System

A system recently built by the writer and described here operates at a frequency of 650MHz and, as with virtually all systems of this nature, aerials being tested are operated in receiving mode. The transmitter is normally placed at a distance of 10 wavelengths, in this case 4·6m, and it is equipped with a three-element (flat plane reflector) beam aerial to concentrate the radiation forward, to provide a sufficiently large illumination area and to reduce reflected signals to a minimum.

The "receiver" consists basically of a simple diode detector to provide a DC voltage from the RF signal picked up by the aerial being tested and which is used (a) to operate a pen chart recorder to obtain either polar co-ordinate or Cartesian co-ordinate plots of radiation patterns or (b) a continuous direct display of a radiation pattern in polar or Cartesian co-ordinates on an oscilloscope screen.

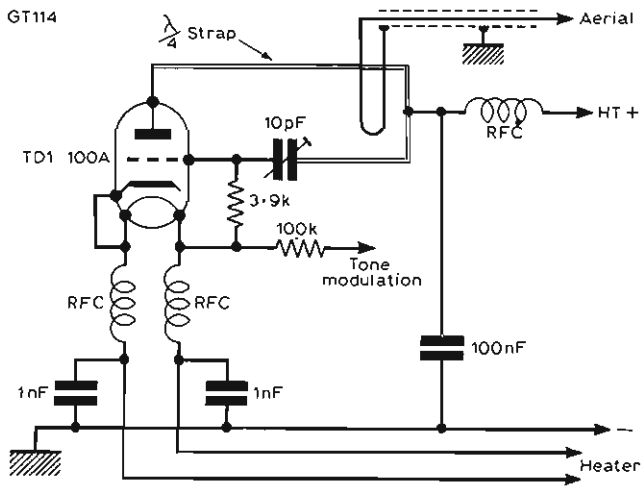


Fig. 1: Circuit diagram of the author's 650MHz transmitter.

The Transmitter

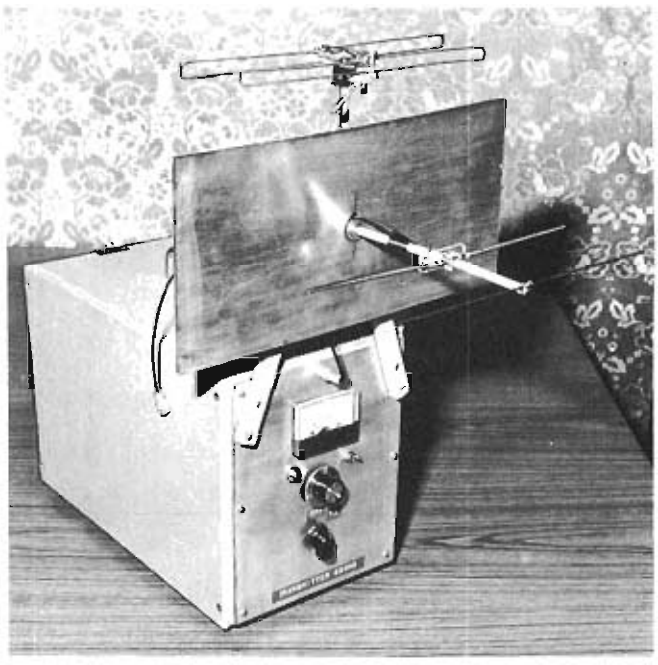
The transmitter is a simple self-excited oscillator using a Mullard TD1-100A valve to provide an RF output at 650MHz of about 2W. Any similar UHF valve would do and frequency stability is not critical provided drift is not more than a few MHz. Audio tone modulation can be applied for quick checks and for demonstration, in which case the model is made to radiate and the space around explored with a single dipole and diode receiver the signal from this being fed to an audio amplifier and speaker. The transmitter must, of course, be completely screened and its output (loop coupled) matched as closely as possible to the transmitting aerial. The circuit used is shown in **Fig. 1** and may serve as a guide to anyone interested in embarking on a similar project

The Measuring System

This system is rather complex in view of the facilities it provides but could be simplified by using a meter to obtain readings for plotting patterns and checking gain, in which case the receiver need consist only of a diode detector, the DC output from this being fed to a micro-ammeter via a simple attenuator.

One of the most important factors in aerial performance measurement is the "reference" to be used and this is normally a dipole. For example, in gain measurement the dipole is first set up and the signal level from this noted. It is then substituted for the aerial to be tested and the level from this ascertained. If the readings are in terms of voltage then the usual formula $20 \text{ Log}_{10} \frac{V2}{V1}$ is used to obtain the gain in dB. In the system described here a rather more sophisticated reference system is employed, particularly in connection with continuous oscilloscope displays and this uses an "electronic dipole" to be described later.

The block diagram **Fig. 2** gives some idea of the complexity of the system, which begins at the aerial being tested, picking up the signal from the transmitter. This is coupled by a rotating loop to the detector and the received signal is rectified, the output being switched to obtain positive or negative (with respect to earth) DC which is fed to a calibrated attenuator. From here the signal goes to a pen-recorder for Cartesian or polar plotting, to a meter for making initial adjustments, or to the oscilloscope DC "Y" amplifier for direct display of Cartesian plots (see various photos). The aerial and polar plotting table are turned by either of two synchronous motors with suitable pulley and/or gear reduction to obtain (a) a slow rotation at about 1 revolution per 30 seconds for pen chart plots or a fast rotation for oscilloscope displays at between 5 and 8 revolutions per second. Directly coupled to the aerial turning shaft are (a) a system for obtaining a sync pulse for each 360° of rotation and pulses for each 10° of rotation which are used for Z modulation (scope "bright up") pulses and (b) the components for generating the electronic dipole signal. The sync and 10° marker pulses are obtained by a light shining through small holes in a perspex disc (painted black)



The 650MHz test transmitter with its 3-element aerial mounted above it.

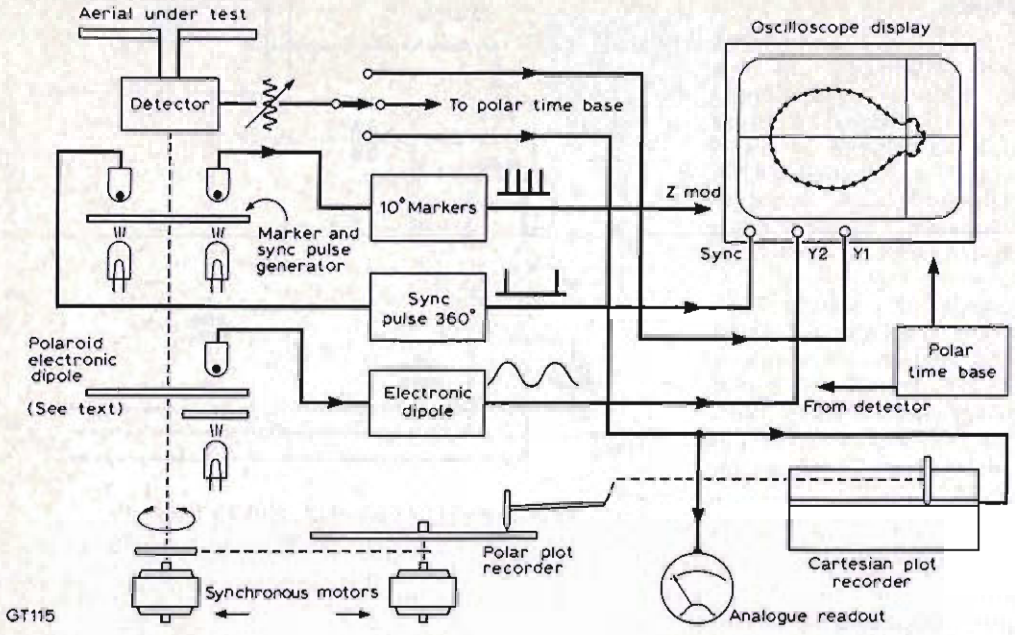
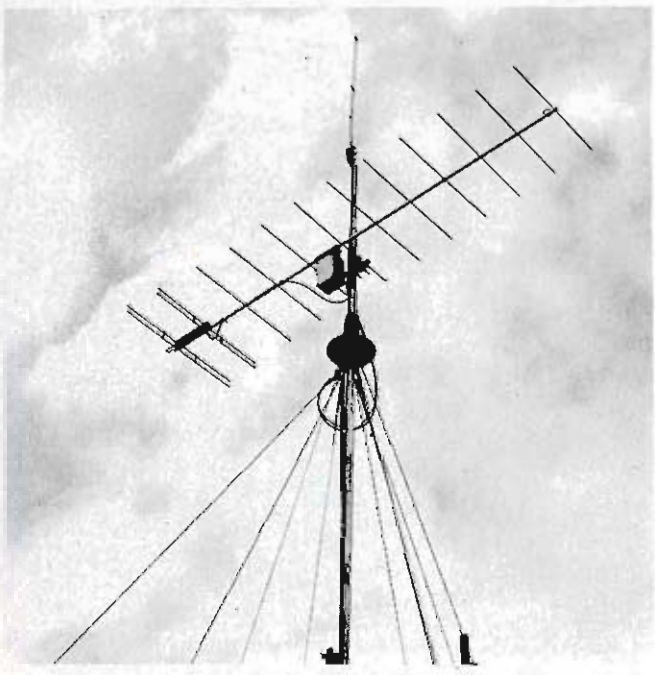


Fig. 2: Block diagram of the performance measurement system.

on to photo transistors, the outputs from which are amplified and shaped into short duration pulses. The disc contains 36 holes for the 10° markers and one for the 360° sync pulse.

The electronic dipole signal is obtained by shining light through a rotating disc of Polaroid material and a fixed piece of Polaroid simultaneously on to a photo transistor. As the light fluctuates sinusoidally the transistor generates two "sinusoidal" DC voltages per revolution, the equivalent of the radiation pattern from a dipole in Cartesian co-ordinates, see **Fig. 3**. The signal is coupled to the Y2 DC amplifier on the oscilloscope via an attenuator so that the level can be set against that from a real "reference" dipole and, of course, retained and displayed simultaneously whilst an aerial is being tested.



A 12-element "ZL Special" mounted on the rotator system atop the author's 60ft mast.

An additional feature in progress of being developed is to provide the oscilloscope (an Advance model OS250) with a controllable circular time base; controlled, that is, from the aerial signal to provide continuous display of patterns in polar form as depicted in the block diagram.

Examples of Pattern Plotting

First some examples of plots from the oscilloscope in Cartesian co-ordinate and, apart from the dipole, I have taken one or two of the aerials described in my articles in the *PW* July 1976 and May 1977. The pattern from a real dipole is shown in **Fig. 4** and, as can be seen, compares very favourably with the "electronic dipole" readout in **Fig. 3**. Each bright spot represents 10° of rotation, through 360°. Now examine the scope readout, **Fig. 5**, from the "ZL Special" end-fire beam described in *PW* May 1977, operating in horizontal mode. The two minor rear lobes are displayed to the right and left respectively. Compare this with the polar co-ordinate plot in **Fig. 6** taken from the same aerial and with the same equipment.

The $^{5}/_{8}\lambda$ ground plane is a very popular aerial but it is not as efficient as one would suppose due to its high-angle radiation. It is omni-directional and, ideally, maximum radiation should be parallel to the ground. As the vertical angle pattern **Fig. 7** shows, maximum radiation is at an angle of about 30° and although some gain is obtained from this aerial over a conventional $^{1}/_{4}\lambda$ ground plane it is wasted in an upward direction. In fact the "gain" on a line parallel to the ground is negative with respect to a vertical dipole. The oscilloscope readout **Fig. 8** shows the same pattern in Cartesian co-ordinate.

Performance Defects

With this system of testing all kinds of defects in performance can be seen readily. Taking again the $^{5}/_{8}\lambda$ ground plane, its normal omni-direction pattern

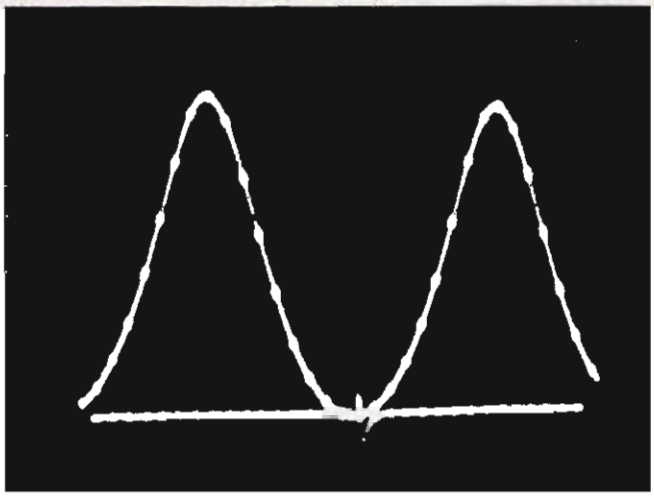


Fig. 3: Oscilloscope Cartesian plot of the "electronic dipole". (See text)

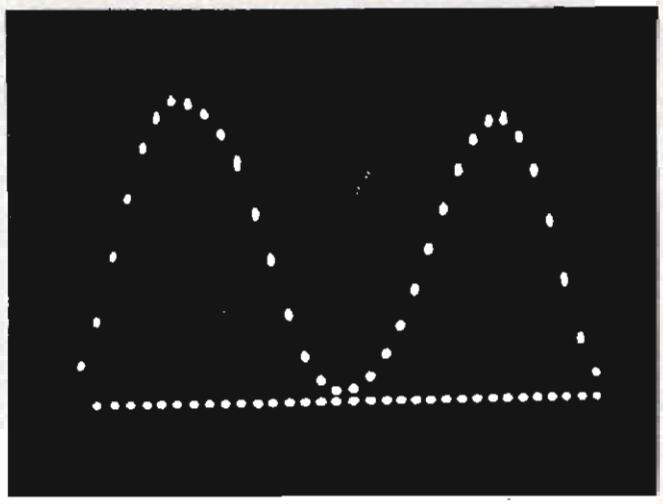


Fig. 4: A Cartesian plot of the response pattern of a real dipole.

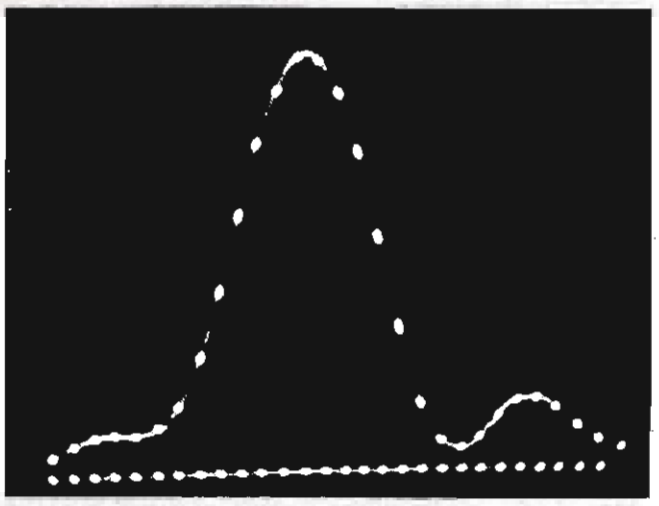


Fig. 5: Cartesian plot of the response pattern of a "ZL Special" array, operating in the horizontal mode.

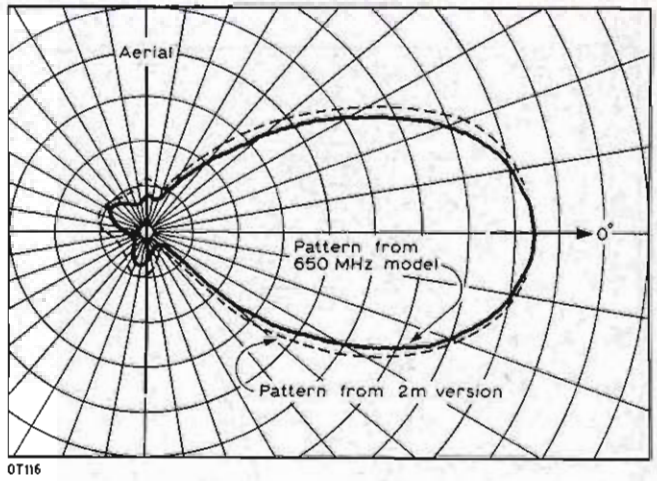


Fig. 6: A polar co-ordinate plot of the aerial of Fig. 5, plotted using the pen chart recorder.

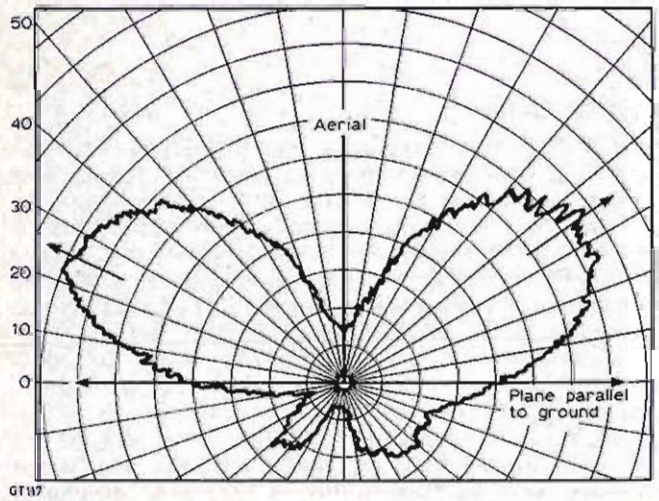


Fig. 7: Vertical radiation pattern of a $\frac{5}{8}$-wave ground plane aerial.

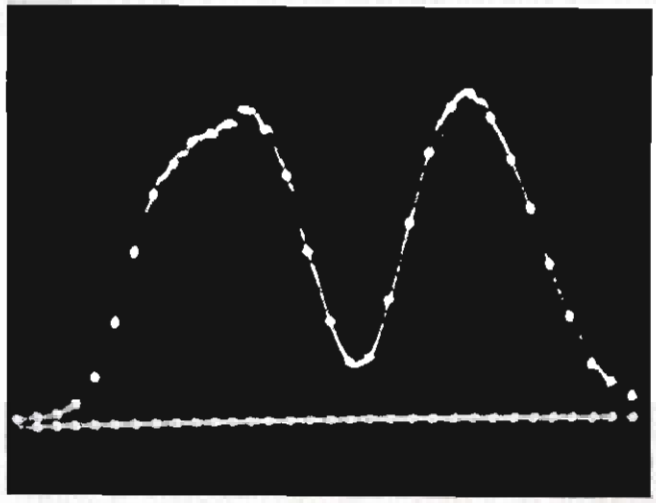


Fig. 8: Oscilloscope Cartesian plot of the response of the aerial of Fig. 7.

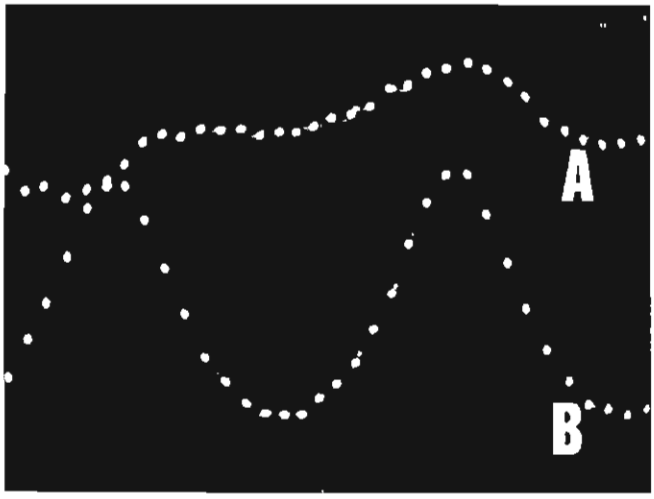
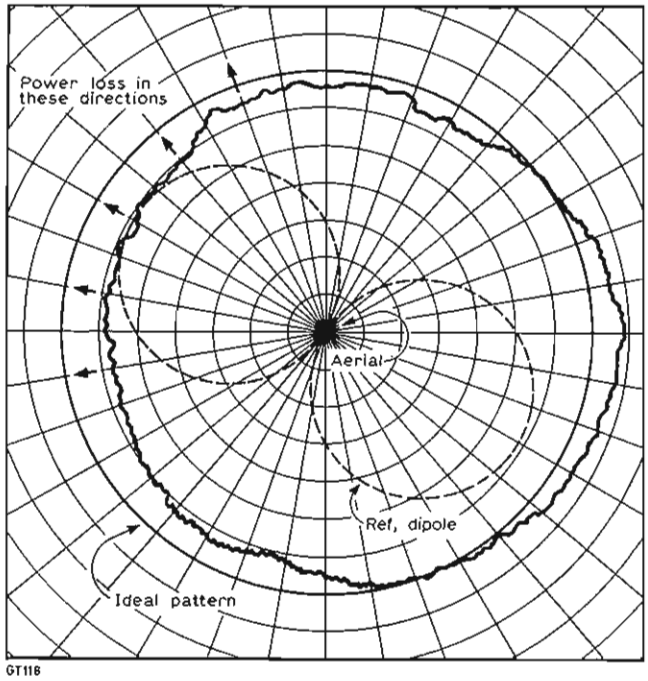


Fig. 9: Trace A shows the distortion of the radiation pattern of an omni-directional aerial due to a nearby resonant conductor. Trace B is a reference dipole.

Fig. 10 (right): The polar co-ordinate plot of the set-up of Fig. 9.



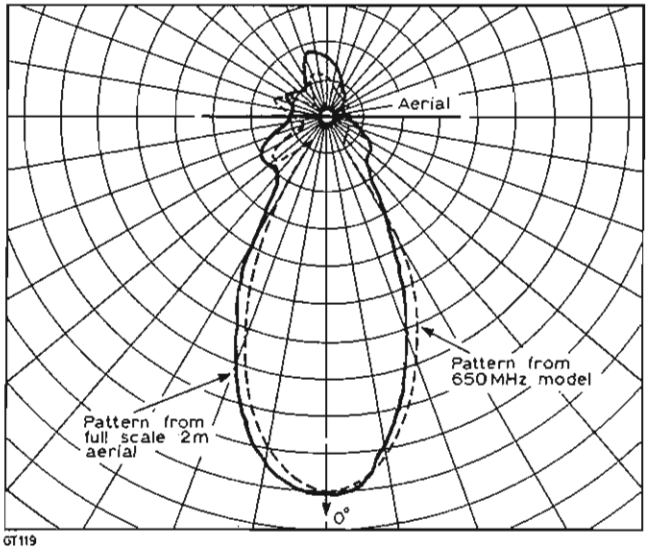


Fig. 11: Horizontal radiation patterns of two 12-element "ZL Special" aerials.

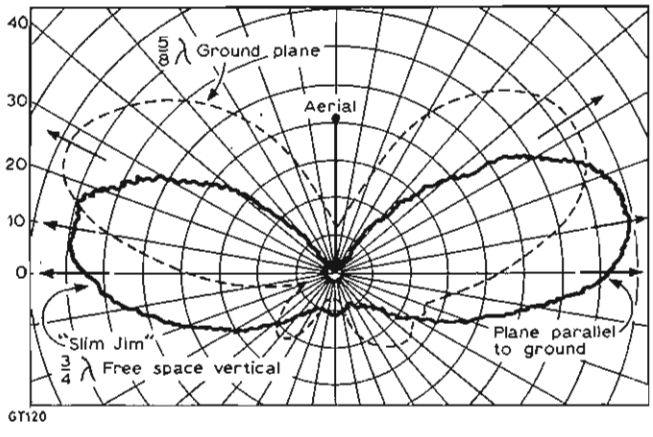


Fig. 12: Comparison of the vertical radiation patterns of a $\frac{5}{8}$-wave ground plane aerial and the $\frac{3}{4}$-wave "Slim-Jim".

should be a circle if the aerial were behaving perfectly. If a mismatch exists, or the aerial is off resonance, the pattern can become distorted i.e., not a perfect circle. The presence of other resonant conductors will also produce this effect. The oscillogram **Fig. 9** shows this quite clearly. The lower trace (B) is a reference dipole pattern. The upper trace should be a straight line, therefore there is a loss of radiated power in some directions. The result is perhaps more clearly illustrated by the polar co-ordinate plot in **Fig. 10** of the same aerial with the dipole pattern again for reference.

A 12 element "ZL Special" mentioned earlier, has been developed for operation on 2m and is now operational at G2BCX, the home station. This aerial started out as a 650MHz model and after adjustment and a few modifications to director spacing and length, yielded a gain (over a dipole) of 14dB. The 2m version is physically much smaller than a Yagi array having the same gain. Its radiation pattern, actually plotted operating on 2m is shown in **Fig. 11** by comparison with the pattern obtained from the 650MHz model, which is shown dotted.

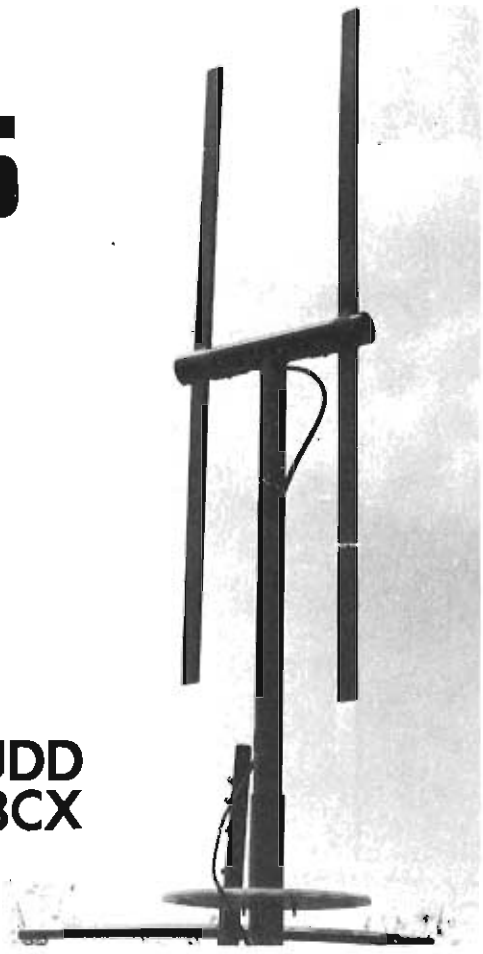
Slim Jim

Another aerial designed and developed with the aid of the model system is an omni-directional "free space" aerial for 2m known at the moment as the "Slim Jim". It has no ground plane radials and is vastly superior to a $^{5}/_{8}\lambda$ ground plane, due to the radiation being almost parallel to the ground. The vertical angle radiation from the full scale 2m version is shown in **Fig. 12**. Compare this with vertical angle radiation from a $^{5}/_{8}\lambda$ ground plane shown dotted in the illustration. Details of both these 2m aerials will be published in the not too distant future.

To anyone contemplating setting up a test system of this nature I must emphasise that the task is not an easy one, but the results, if they are reasonably accurate, are highly rewarding. ●

COMPACT 2m BEAM AERIALS

F. JUDD
G2BCX



THE previous article "Vertical Aerials for 144MHz" (*Practical Wireless July 1976*) dealt with omnidirectional types such as the ground plane and vertical colinear which are convenient for transmitting or receiving in any direction but have relatively little gain over a dipole. For example, a 4-element colinear has but 4·3dB gain and is a sizeable aerial, some 14ft or so long. Beams are the only way of obtaining relatively high directivity and gain and there are many to choose from with the Yagi or parasitic array being the most popular.

However, fairly small but efficient beam aerials for 144MHz are not difficult to make and gain as high as 10dB over a dipole is possible without resorting to large numbers of elements as are necessary for Yagi or colinear arrays. The corner reflector aerial, which employs only one driven element, may be an exception and although a high gain, around 12dB or more, is possible, the reflector itself is of somewhat unwieldly dimensions.

TWO DRIVEN ELEMENTS

Small beams with a useful degree of directivity and gain may be derived from "end-fire" or "broadside" arrays consisting of two driven radiators spaced a specific distance apart with the current in each phased according to the directivity required. In the case of the "end-fire" array the pattern has zero radiation broadside (at right angles) to the plane of the array and maximum end-fire radiation when the spacing between the elements is a half-wavelength or less and the currents in the elements are equal in amplitude but in opposite phase i.e. 180° phase difference.

The configuration of this array is shown in Fig. 1 in which the spacing "d" may be from $^1/_8\lambda$ to $^5/_8\lambda$ to obtain the requisite horizontal plane end-fire radiation pattern when the array is vertical as in Fig. 2(a) and looking down on the ends of the elements. Radiation in the vertical plane i.e., with reference to an angle to the ground, will be as shown in Fig. 2(b).

To obtain "broadside" radiation, at right angles to the array, the spacing between the elements is usually a half-wavelength and the elements fed in phase. The available directivity/gain is greatest when the elements are spaced $^1/_2\lambda$ or $^5/_8\lambda$ but not closer. The end-fire array is of greater interest since considerable gain can be obtained with closer spacing between the elements thus allowing for a more compact aerial plus uni-directional or bi-directional radiation pattern as required. Such an aerial may be operated horizontally (for horizontal polarization) or vertically (for vertical polarization).

Greatest bi-directional gain is obtained when two driven half-wave elements are spaced 0·125λ apart and fed out of phase as in Fig. 3. The gain is about 4dB with reference to a half-wave dipole. However, for 144MHz operation the high feed point impedance presents a problem as it is not suitable for direct connection to commonly used 50Ω co-axial cable although this can be overcome by the use of a matching stub.

Since beam aerials have to be rotated for maximum radiation in a desired direction there is little point in using a bi-directional array. Better to use a uni-directional system and obtain a little more gain. This can be achieved with a two-element close spaced array in which one element is fed 135° out of phase with respect to the other. The radiation pattern then becomes a cardioid as shown in Fig. 4 and remains virtually the same whether the aerial is used vertically or horizontally.

An aerial based on this arrangement, to provide even more gain, was designed by the writer some 26 years ago and is known as the "ZL Special" although it was originally intended for HF bands operation. It employs two driven elements fed 135° anti-phase but the element lengths are such that one operates as a driven element/director whilst the other behaves as a driven element/reflector. The radiation pattern is cardioid as in Fig. 4 and the gain a little over 6dB with reference to a half-wave dipole.

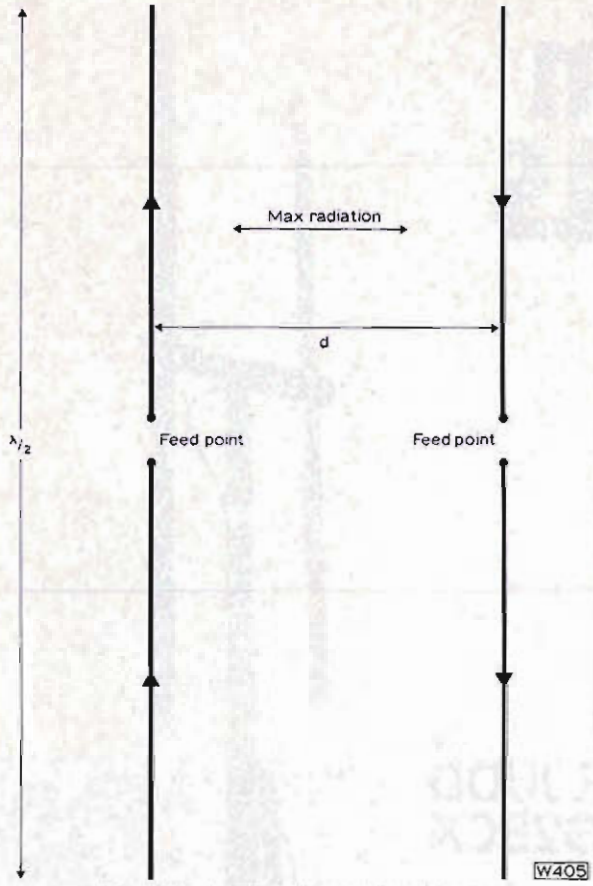


Fig. 1: Configuration of an end-fire aerial array.

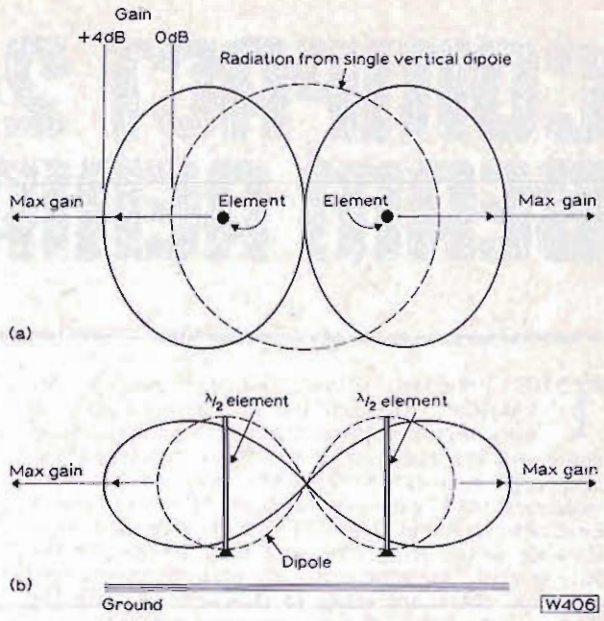


Fig. 2: Radiation patterns and gain of an end-fire array compared with a dipole.

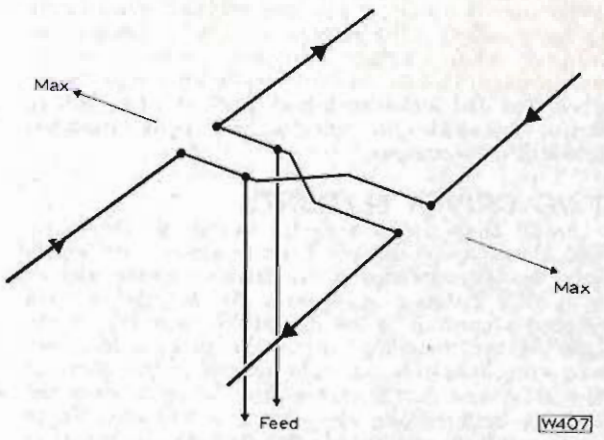


Fig. 3: One method of feeding an end-fire array (see text).

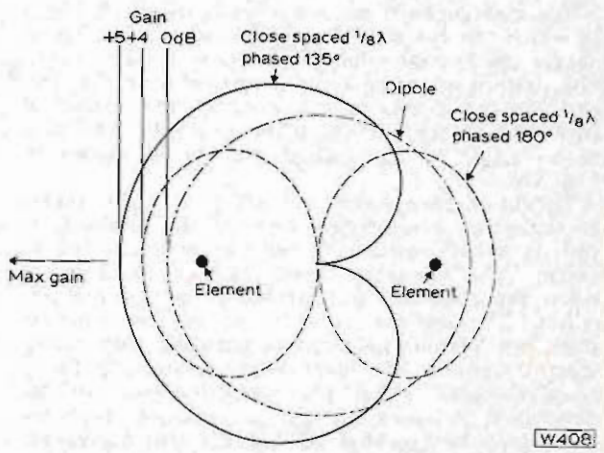


Fig. 4: Gain and radiation pattern of a close spaced end-fire array with currents 135° anti-phase.

"ZL SPECIAL" FOR 2M

This beam is identical to the original model except that an alternative feed method to suit 50Ω co-axial cable was necessary and the element lengths are appropriate for 2m band operation. It is easy to construct and the elements and phasing line may be made from copper wire, copper tube or even 300Ω ribbon feeder. Quite a large number of this 2m version have been constructed and tested and being a very compact aerial it has proved ideal for use indoors since it is not generally affected by the proximity of walls and even conductive structures, providing these are not too close.

This beam has a broadband characteristic and properly constructed and adjusted should exhibit around a 1:1 SWR over the whole 2m band. Constructional details are shown in Fig. 5 and providing the phasing line length and the element spacing and lengths are adhered to, the materials for these may be as mentioned above. If 300Ω ribbon feeder is used the distance between conductors will of course be that of the feeder itself.

The small air-spaced 20pF variable capacitor is necessary to achieve a correct match to 50Ω co-ax cable and is adjusted for minimum SWR at 145 MHz. Not more than about 10pF of this capacitance should be necessary to achieve this. *Do not use mica or ceramic type trimmer capacitors.* It is important to curve the feed line away and down as shown in the inset in Fig. 5 when the aerial is operated vertically

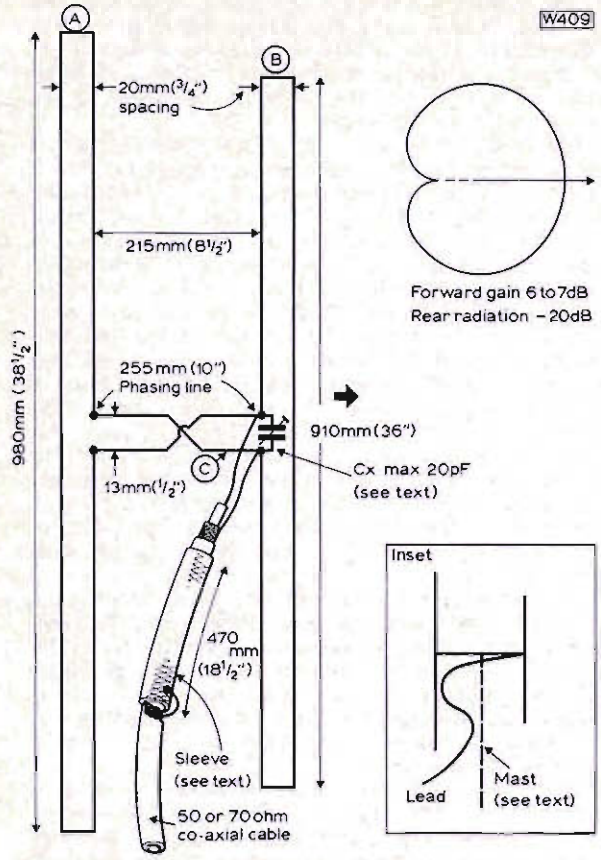


Fig. 5: Details for the construction of a ZL Special aerial for 2 metres.

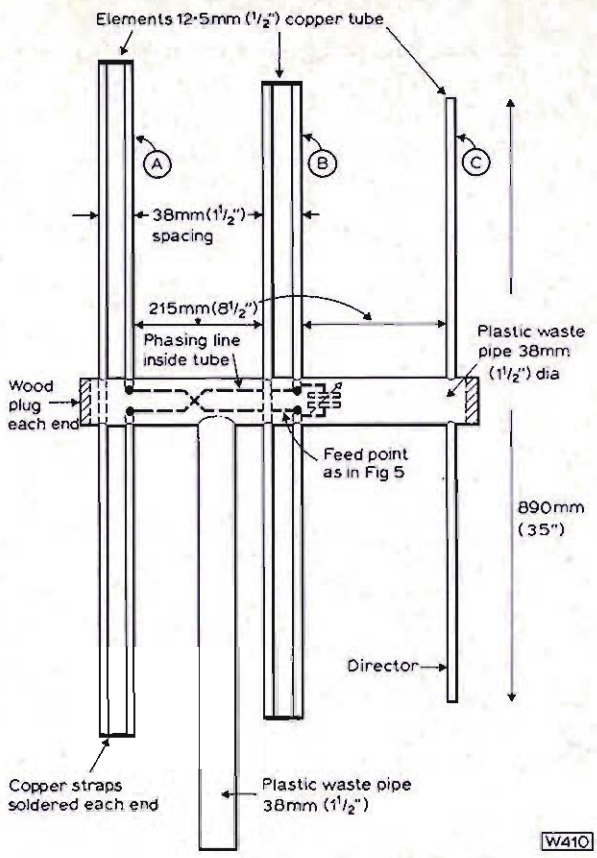


Fig. 6: Construction of a three element ZL Special beam.

and the matching capacitor should be adjusted only when the feeder has been secured. The short stub mast used to support the aerial must be of insulating material, wood or plastic tube and extended to a few inches below the bottom ends of the elements when it may be coupled to a metal mast. The gain remains the same when the aerial is used horizontally but the cardioid pattern becomes a little narrower to the sides. Note the unbalance-to-balanced co-axial connection using a $\frac{1}{4}\lambda$ sleeve which is bonded to the main co-axial braid only where shown, at point X in Fig. 5. The end near the feed point is not connected to anything. For use outdoors the feed connections and tuning capacitor must of course be protected from weather as must the elements and for this a small plastic electrical junction box could be used. The elements and supporting frame (this must be wood or plastic tube) can be given two or three coats of polyurethane varnish.

This aerial is used by the writer on a cabin cruiser (G2BCX/MM) at a height of only 9 feet above the water and so far 10 European countries as well as many UK DX stations have been worked. The photo shows the aerial enclosed entirely in plastic "plumbing" tube for complete protection from weather and salt water. The aerial is also ideal for portable work as it will fit comfortably in the boot of a car.

Since the basic ZL is a driven array and the radiation pattern uni-directional it has been found possible to add parasitic director elements to obtain an increase in forward gain. One director mounted

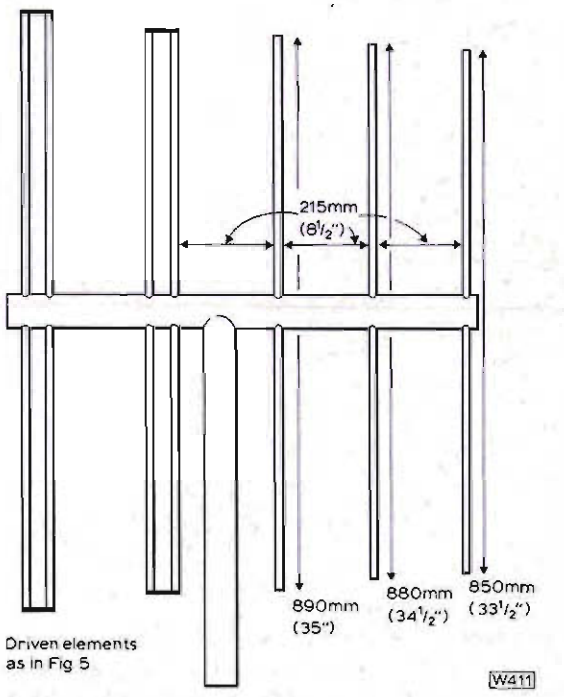


Fig. 7: Details for the director lengths and spacing for a five element ZL Special. Other constructional details as in Fig. 6.

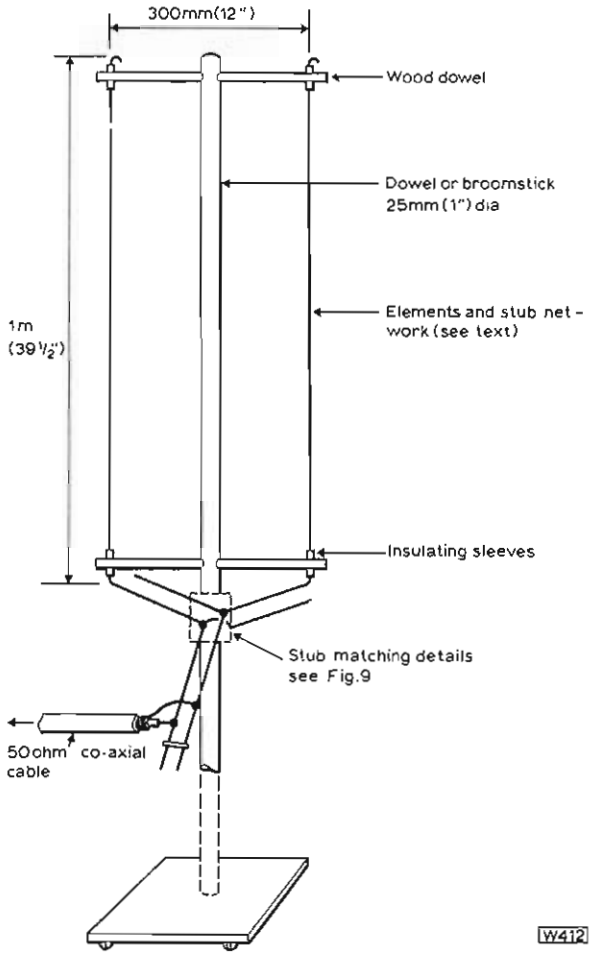


Fig. 8: Details for the construction of a bi-directional end-fire array with about 4dB gain.

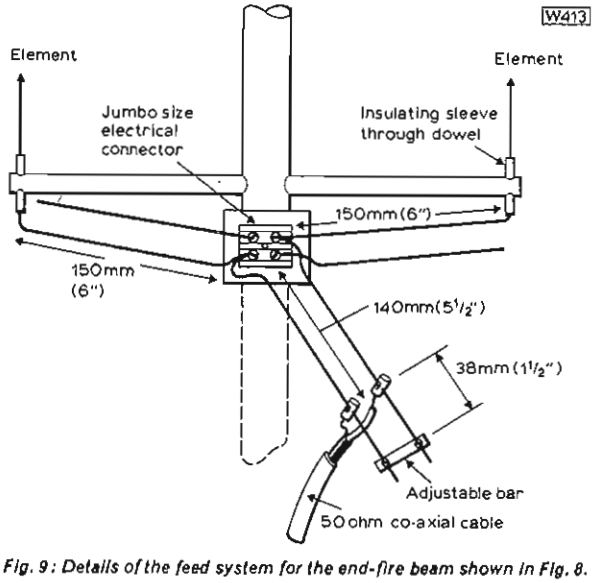


Fig. 9: Details of the feed system for the end-fire beam shown in Fig. 8.

0·12λ in front of the main driven element (B in Fig. 5), increases the forward gain by slightly over 2dB thus providing a total gain of 8dB which is quite considerable for a beam measuring only about 50cm (20in.) from front to rear. The addition of three directors, still making the beam only about 1·2m (40in.) high, yields a forward gain of a little over 10dB which is comparable with that of an 8-element Yagi having a physical length of about 2·8m (110in.), or twice the length.

The construction of a ZL with directors is much the same as for the basic aerial shown in Fig. 5 except that the element support is extended for mounting the directors. This must be insulating material, such as wood or plastic tube, and one suggested method of construction, particularly suitable for outdoor use, is given in Fig. 6. The main support which consists of the boom and stub mast is made of plastic pipe. The stub mast is fitted into the boom either by cutting a hole in the boom and gluing the mast in with Araldite, or by using a pipe "T" piece to make the join. The copper tube elements are fitted tightly into holes through the boom section and secured by screws through the side of the pipe. The phasing line which may be two copper wires (12 to 16 SWG) are inside the tube as is the small capacitor. To ensure that the phasing lines do not touch, they may be insulated with sleeving.

This 3-element ZL Special has been tested over a long period and operated both vertically and horizontally with considerable Continental DX worked. The half-power beamwidth (3dB) is about 90° and radiation directly from the rear is about 25dB down although the overall radiation pattern is still cardioid but narrower than that from the 2-element ZL Special.

The addition of two more directors, making a total of three, and the aerial therefore a 5-element version, will provide a gain of about 10dB. The aerial is still not very large and may of course be operated vertically or horizontally. Construction is the same as for the 3-element version except for the three extra directors cut to length and spaced as shown in Fig. 7. Note that the amount of capacitance required across the 50Ω feed to effect a good match may be much less or even nil with the directors in use.

VERTICAL END-FIRE ARRAY

This is relatively easy to construct and will provide about 4dB gain over a dipole and is bi-directional. It needs only to be turned through 90° to achieve all round coverage and being compact could prove useful to flat dwellers unable to put up an aerial outside. It consists of two half-wave radiators fed 180° anti-phase to produce the radiation pattern as in Fig. 2a. It may be assembled on a wooden frame and the elements and stubs can be made from copper wire as shown in Fig. 8. It could also be set up to rotate on a floor stand, as the extension of the diagram illustrates, making it suitable for indoor use. Details of the matching stub and feed are shown with more detail in Fig. 9. Adjustment for minimum SWR is carried out by sliding the shorting bar along the stub in conjunction with moving the tapping point of the 50Ω co-ax feeder. The approximate positions for these are given in Fig. 9 and very little further adjustment should be needed to obtain an SWR approaching 1:1 over the whole 2m band. Used in the writer's workshop at about 10ft. above the ground, this aerial could receive a substantial signal from the GB3PI repeater nearly 40 miles away. PW

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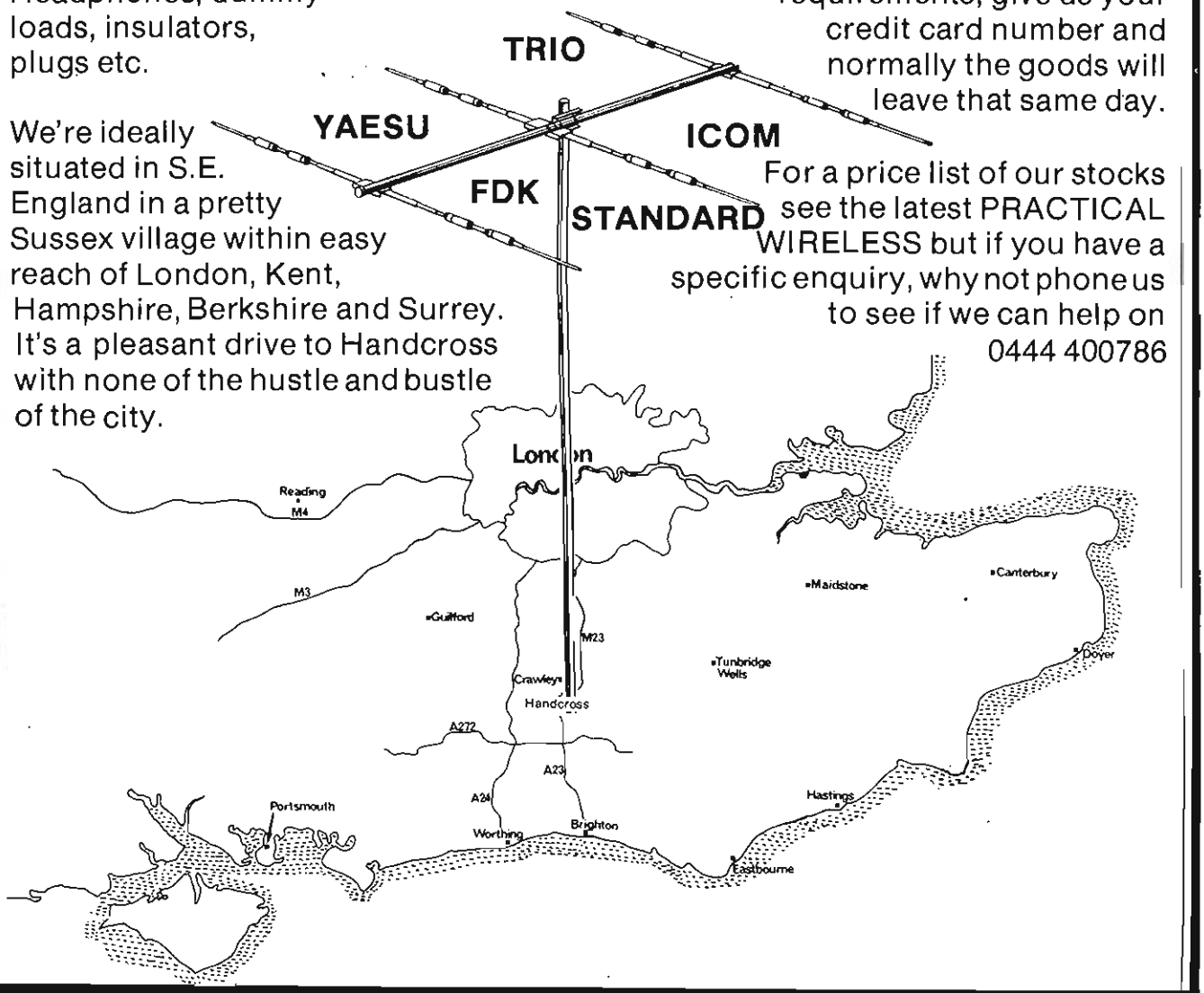

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'SLIM JIM' ULTRA SLIM JIM

2-METRE OMNI VERTICAL AERIAL

F.C.JUDD G2BCX

The original "Slim Jim" omni-directional vertical aerial for 2 metres, designed by the writer, is fully described elsewhere in this publication. It has proved to be one of the most popular single-element aerials for 2m operation because of its low-angle radiation, high efficiency and unobtrusive appearance, etc. It is now being used throughout the UK and in many other countries including Holland, Belgium, Norway, Iceland, New Zealand, Australia and the USA. The newer and even less obtrusive version described here also incorporates a small capacity plate, to allow the aerial to be tuned to exact resonance at the centre of the band. The performance parameters are otherwise the same as the original.

The various diagrams give all the details required for the construction and also the materials used. The aerial itself can be made from a single length of aluminium rod 5mm or 3/16in diameter, which will bend quite easily at top and bottom to the required radius. To obtain a smooth bend first clamp into a vice a short length of metal or wood of a diameter a little less than that required for the bend. This functions as a "former". Heat the element at the point of the bend and then slowly bend the rod around the "former". *Make the bend gradually and re-heat the element as necessary to keep it pliable. Don't overdo the heat.* Practice on a scrap length of rod first. It will be necessary to thread the various spacers onto the long section of the element before bending the ends.

The diagrams in Fig. 1 show: (a) the general configuration of the aerial and its voltage and current distribution. Details for the insulator between one side of the top of the quarter-wave stub section and the driven element proper, carrying the capacity plate, are shown in (b). The lower section of the aerial, i.e. the stub section, is enclosed as shown in a length of plastics water pipe and supported inside with circular spacers which should be bonded to the element with Loctite or Araldite before the pipe is fitted. The plastics tube has a length of dowel inserted at the lower end to provide a solid section for mounting the aerial on a mast. This can be extended if required, for example, for car bumper mounting which will allow the aerial to be used for mobile operation.

The remainder of the constructional details, e.g. element spacers, capacity plate and upper section etc. are given in Fig. 1(c), (d) and (e). The ends of the element that fit into the insulator should be bonded in with Loctite or Araldite. The 50 ohm coaxial feed cable is taken into the tapping point on the stub section via a hole in the plastics tube just above the dowel insert. Connection to the elements is best made by small brass or copper clips as shown in Fig. 2(a) to facilitate adjustment for the correct feed point.

Adjustment and Final Assembly

Adjustment for the correct feed point and to the capacity plate must be made before the plastics tube is fitted. Connect up *the full length of coaxial cable to be used* and stand the aerial in a position clear of other conductors. This can be indoors in the centre of a room with the aerial about 1m clear of the ground. Set the capacity plate in line with the insulator and find a feed point which gives the lowest possible v.s.w.r. (or maximum power to the aerial). If the v.s.w.r. doesn't come down to less than, say, 1·5 to 1, turn the capacity plate to about 45° and reset the tapping point. It is possible that little or no capacity at all may be necessary, i.e. the plate may be right round at 90° to the insulator. However, with adjustment of this plate and the position of the feed point, the v.s.w.r. should come right down to near 1 to 1, say 1·2 to 1 or less, depending on the quality of the feed cable, which should be UR67 or equivalent if a long run has to be used, i.e. longer than about 10m. Otherwise UR43 will be satisfactory.

Fit the plastics tube section with the cable through as in Fig. 1 (e) and make a final check on v.s.w.r. Bond the top circular spacer level with the top of the plastics tube with Loctite or Araldite. Also seal the entry points of the elements through the top so that water cannot enter. Araldite will be suitable for this. Different ways of mounting the aerial on a mast are shown in Fig. 2 (b), (c) and (d). The plastics tube and indeed the whole aerial can then be given a couple of coats of grey or white paint.

A final suggestion. If the top section of the aerial from a short distance above the insulator is made detachable but joinable, by means of metal sleeves with set-screws for example, it can be dismantled into two parts of convenient length for carrying about for portable use. •

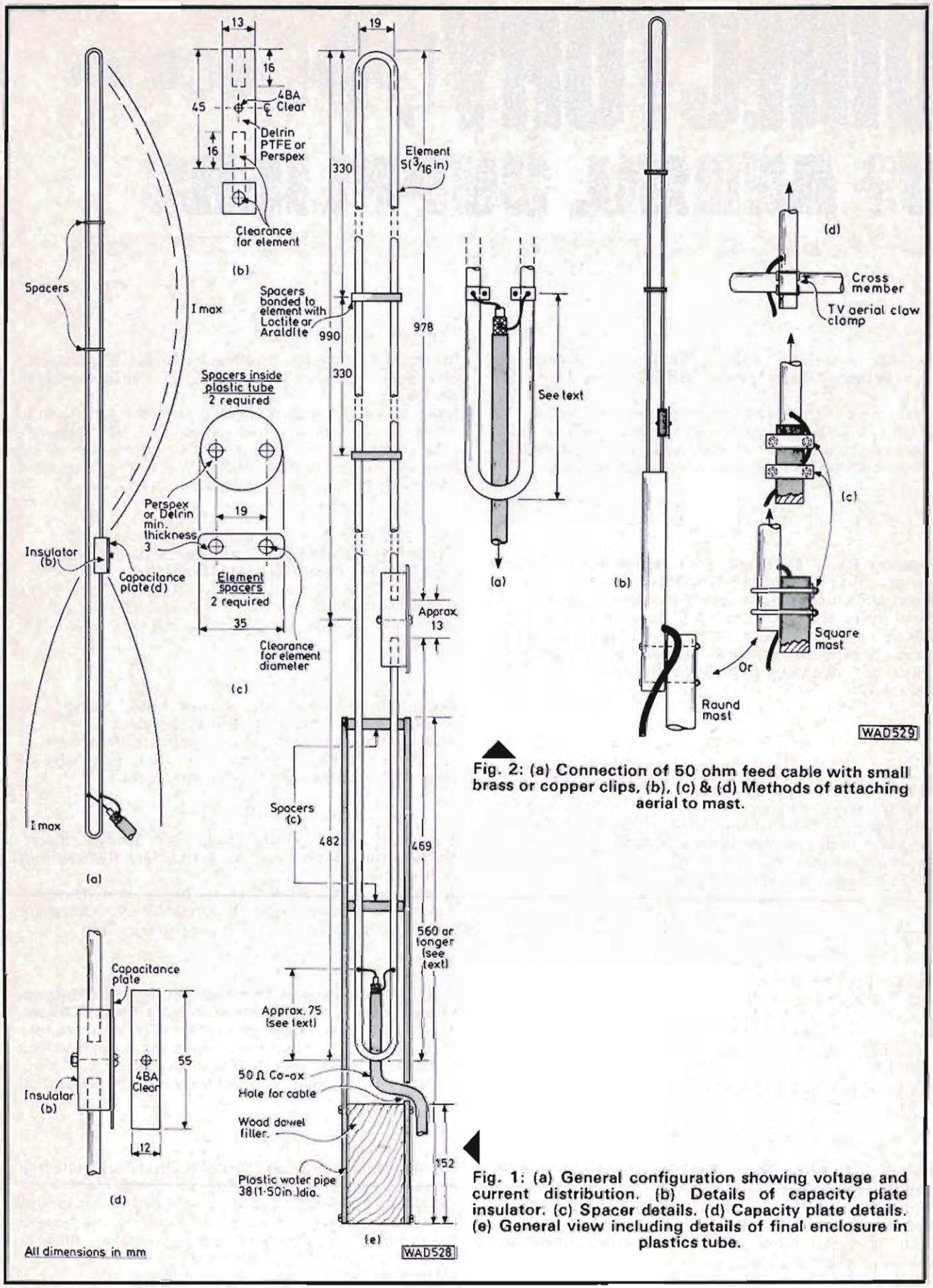

Fig. 2: (a) Connection of 50 ohm feed cable with small brass or copper clips, (b), (c) & (d) Methods of attaching aerial to mast.

Fig. 1: (a) General configuration showing voltage and current distribution. (b) Details of capacity plate insulator. (c) Spacer details. (d) Capacity plate details. (e) General view including details of final enclosure in plastics tube.

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Another manufacturer who makes a very exhaustive range of aerials for domestic use for all TV bands and f.m. radio including necessary hardware and cables. In addition, selected items from the "Expert" range are available for the DX enthusiast who requires aerials for CCIR channels.

Bantex Ltd., Abbey Road, Park Royal, London NW10 7SJ. Tel: 01-965 0941.
This company manufactures a wide range of aerials including h.f., v.h.f. and u.h.f. mobile and fixed station types complete with cables, connectors, mounting brackets and general hardware. Also included in the range are marine antennae.

Bredhurst Electronics, Mid Sussex House, High Street, Handcross, E. Sussex RH17 6BW. Tel: Handcross (0444) 400786.
Suppliers of various makes of h.f. and v.h.f. aerials, both mobile and fixed, beam types and verticals, masts, rigging, cables, connectors; a complete range of aerial measurement equipment and in-line watt meters, also transmitting and receiving only aerial tuning units.

Cambridge Kits, 45 Old School Lane, Milton, Cambridge CB4 4BS. Tel: Cambridge (0223) 860150.
Products from this company include an Antenna Noise Bridge for checking resonance and radiation resistance of aerials, an in-line crystal calibrator and two v.l.f. converters.

Datong Eleetronics Ltd., Spence Mills, Mills Lane, Bramley, Leeds LS13 3HE. Tel: 0532-552461.
Manufactured products include specialist converters and an 'Active Antenna System' for s.w.l. use. Systems generally cover the h.f. and v.h.f. spectrums.

Electronic Mail Order Ltd., 62 Bridge Street, Ramsbottom, Bury, Lancs. BL0 9AG. Tel: Ramsbottom (070-682) 3036.
A range of aerial amplifiers are manufactured, one of which tunes over the 2 metre and aircraft bands. Others are for domestic v.h.f. and u.h.f. radio and television.

G2DYM Aerials and Products, R. Benham-Holman, "Cobhamden Castle", Uplowman, Nr. Tiverton, Devon.
Manufacturers and suppliers of anti-interference and anti-TVI aerials, custom built s.w. aerials and aerial matching units. This company provides a complete consultancy service on all matters regarding aerials and their installation.

Jaybeam Ltd., Sandfield Close, Moulton Park Industrial Estate, Northampton NN3 1QQ. Tel: (0604) 46611.
A vast range of domestic aerials of all types can be supplied to cover all TV and f.m. bands including the famous "Multibeam" and "Parabeam" types. A complete range of hardware, cables and connectors can be supplied as well as aerial amplifiers, power units and rotators.

Lowe Electronics Ltd., Bentley Bridge, Chesterfield Road, Matlock, Derbyshire DE4 5LE. Tel: Matlock (0629) 2817/2430.
Suppliers of a complete range of h.f., v.h.f. and u.h.f. aerials of all types and makes, and a range of aerial characteristic measurement equipment including s.w.r. and noise bridges.

Mosley Electronics Ltd., 196 Norwich Road, New Costessey, Norwich NR5 0EX.
A wide range which includes aerials for most purposes from 10 to 160 metres. Both vertical and horizontal types are available with a range of traps, baluns, masts, rotators and usual fixing hardware.

Panorama Antennas Ltd., 73 Wadham Road, London SW15 2LS. Tel: 01-874 5300/01-870 5192.
Mobile and portable h.f., v.h.f. and u.h.f. aerials complete with all types of connectors, mounting brackets and general hardware.

Partridge Electronics Ltd., 5 Partridge House, Prospect Road, Broadstairs CT10 1LD. Tel: Thanet (0843) 62535.
Manufacturers and suppliers of the famous VFA "Joystick" antenna system complete with a.t.u., cables and connectors, as well as a complete range of hardware, accessories, cables and aerial systems for all m.w. and s.w. broadcast bands.

Randam Electronics, 4 Severn Road, Chiltern, Didcot, Oxon OX11 0PW. Tel: Abingdon (0235) 83328/24844.
Complete range of TONNA v.h.f. and u.h.f. aerials, fixed, portable and mobile. Andrew coaxial cables. All types of connectors and a range of aerial erection hardware including brackets, guy wires, clamps, bolts, etc.

South Midlands Communications Ltd., S. M. House, Osborne Road, Totton, Southampton, Hants. SO4 4DN. Tel: Totton (0703) 867333.
Suppliers of a complete range of h.f. and v.h.f. aerials, cables, connectors, rotators, masts and towers, riggings and fittings. Also included in their range are r.f. power meters, dummy loads, coaxial relays and switches and antenna tuning units.

South West Aerial Systems, 10 Old Boundary Road, Shaftesbury, Dorset. Tel: (0747) 4370.
Suppliers of a complete range of domestic aerial systems for Bands I to V complete with aerial amplifiers, masts, cables and general hardware. A vertical whip for m.w. and s.w. use is also available, along with an advisory service on all problems associated with domestic aerials.

Stephen-James Ltd., 47 Warrington Road, Leigh WN7 3EA. Tel: (0942) 676790.
Stock a good range by most leading manufacturers of aerials, preselectors, filters, changeover switches, aluminium masts, clamps, rotators and general hardware.

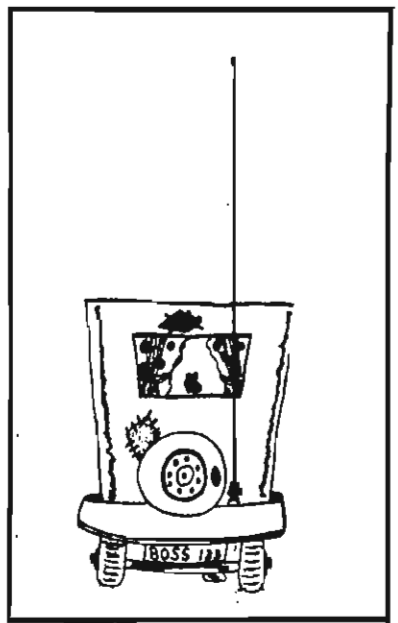
Telecommunications Accessories Ltd., Thame Industrial Estate, Bandet Way, Thame, Oxon. OX9 3SS. Tel: Thame 3621/2/3.
The "Cushcraft" range of antennas is featured by this company, which includes types for h.f., v.h.f. and u.h.f. A feature of this range are the colinears for v.h.f. and u.h.f. and the multi-band verticals for h.f. use.

TMP Electronic Supplies, Britannia Stores, Leeswood, Mold, Clwyd, North Wales CH7 4SD. Tel: Pontybodkin (035-287) 846.
Suppliers of Jaybeam and ASP fixed and mobile aerials and Yaesu equipment which includes power and v.s.w.r. meters. Also available are Amidon toroidal cores, aerial wire and rigging equipment, rotators, cable, books and maps.

Waters and Stanton Electronics, Warren House, 18/20, Main Road, Hockley, Essex. Tel: Hockley (03704) 6835/4965.
Suppliers of complete h.f. and v.h.f. aerial systems, rotators, masts, rigging gear and aerial characteristic measurement equipment.

Western Electronics Ltd., Fairfield Estate, Louth, Lincs. LN11 0JH. Tel: Louth (0507) 604955.
This company supplies a complete range of "Emoto" aerial rotators and position indicators; a range of h.f. beam antennas and a good range of towers and masts. Other products include aerial changeover switches, baluns, traps, dipole centres and a complete 4-band trap dipole.

Bantex FOR ANTENNAS



Bantex make a fine range of Communication Antennas: Marine MF and VHF, HF Mobile and Fixed Station and VHF/UHF Mobile and Fixed Station.

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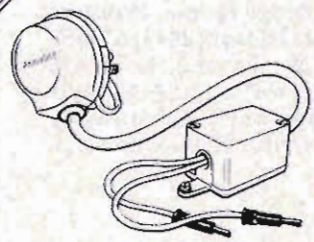
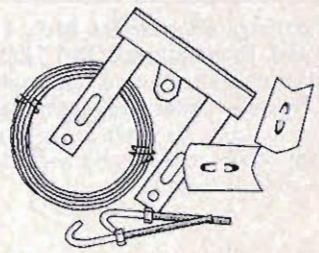
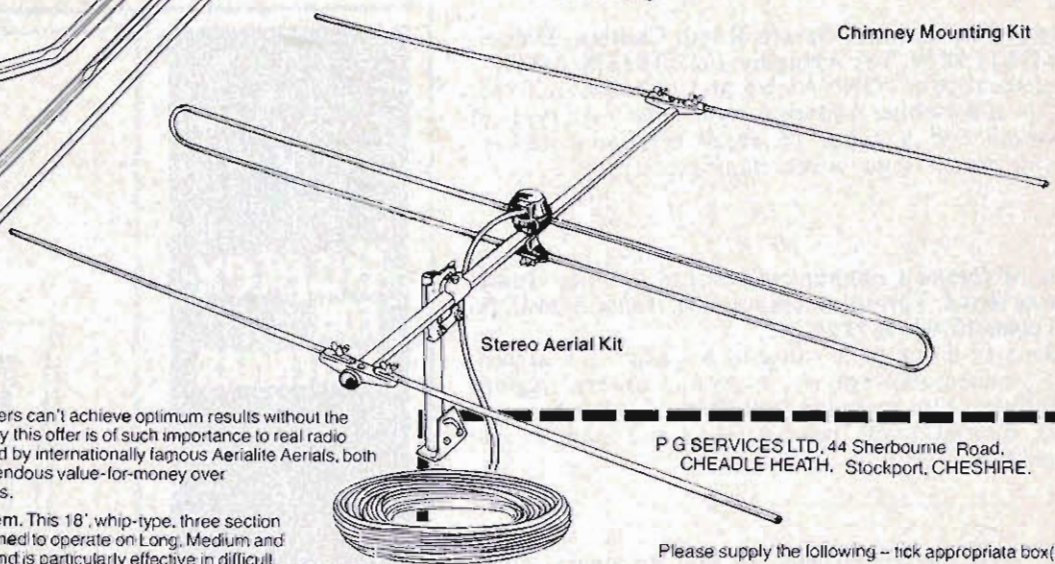




Chimney Mounting Kit



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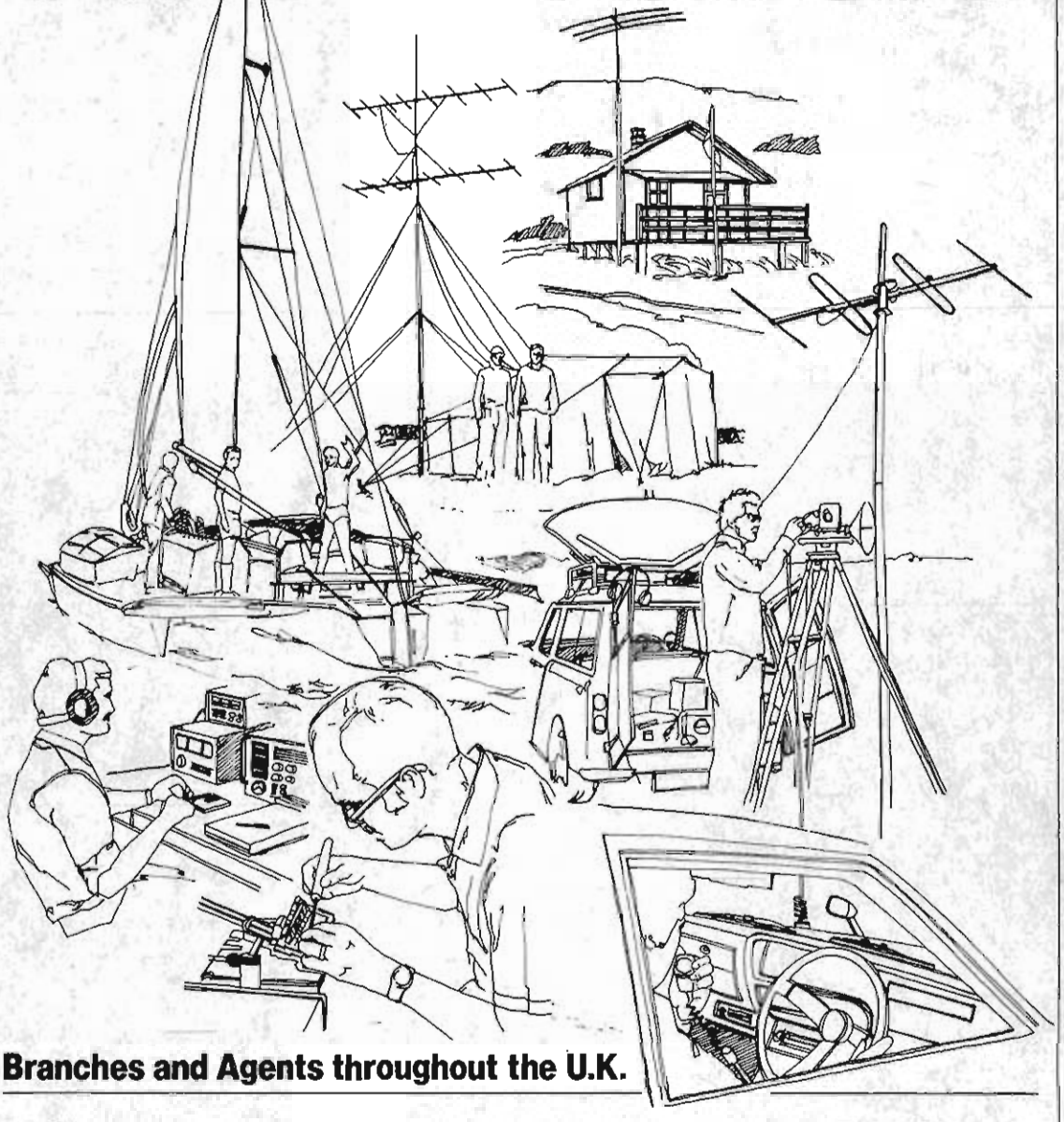

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